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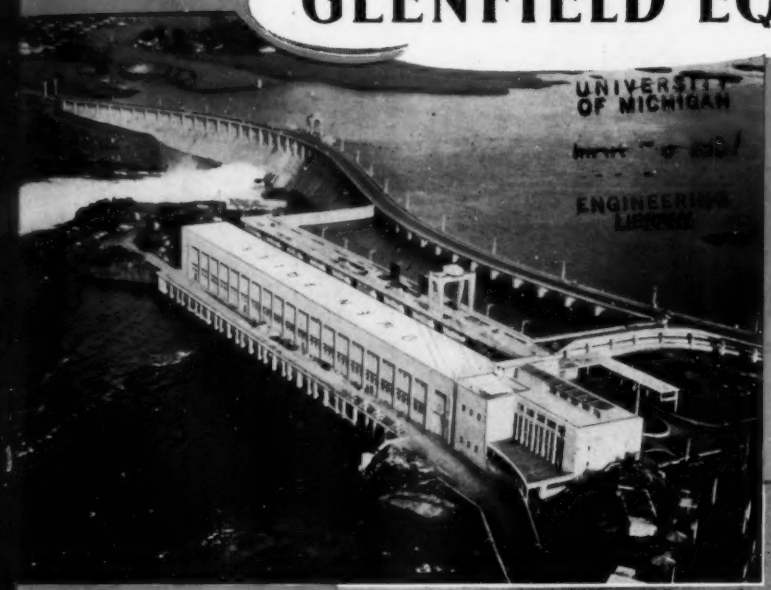

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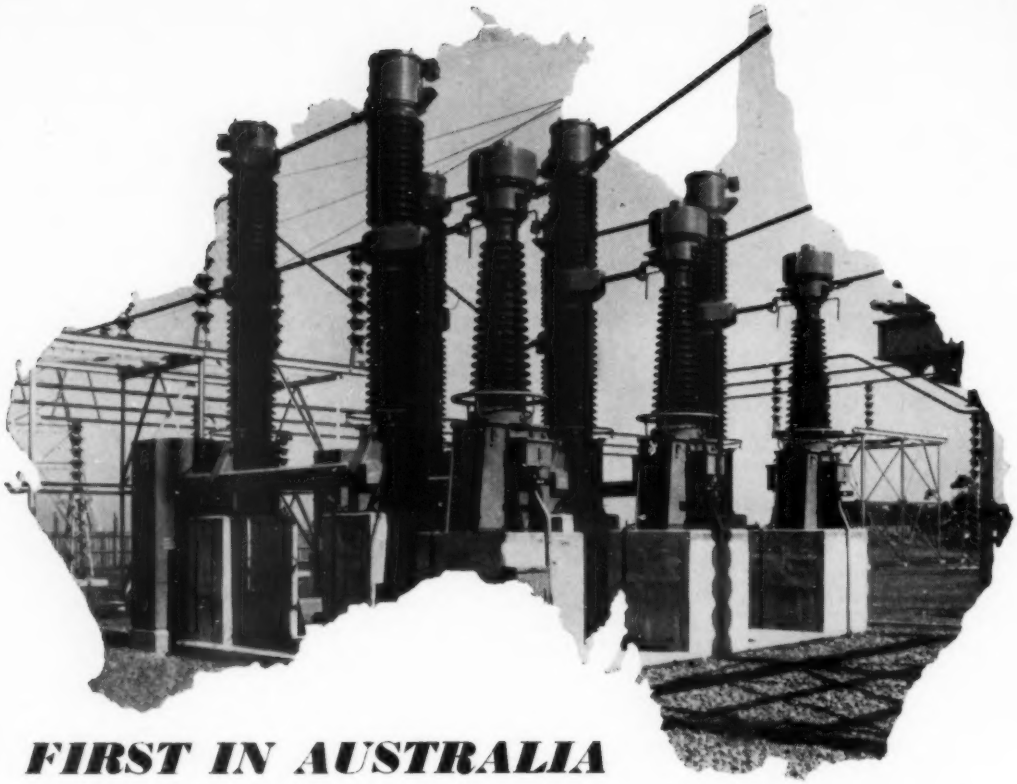

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Volume 9 Number 3

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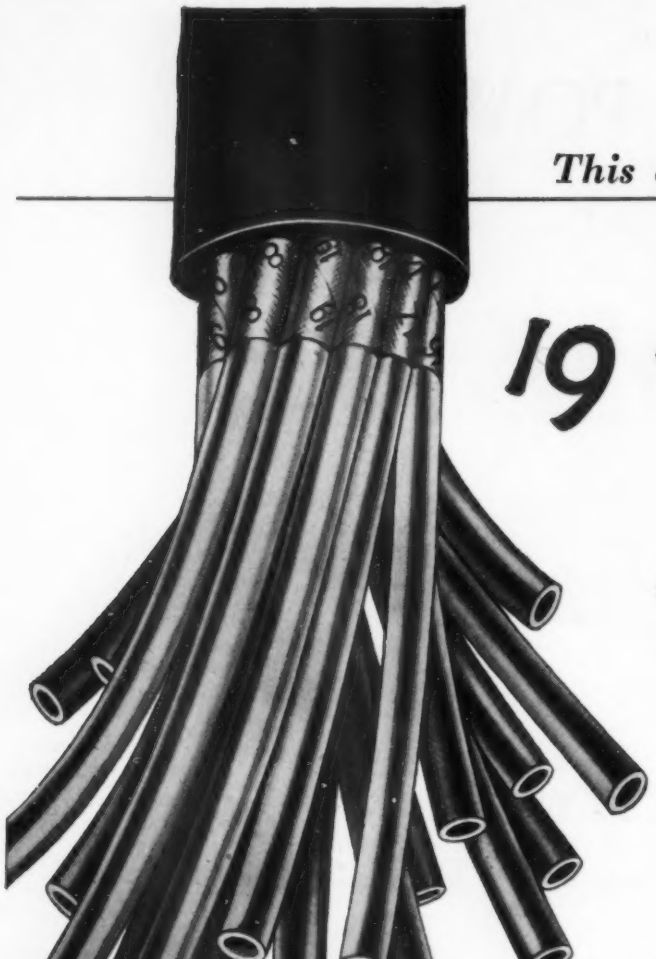

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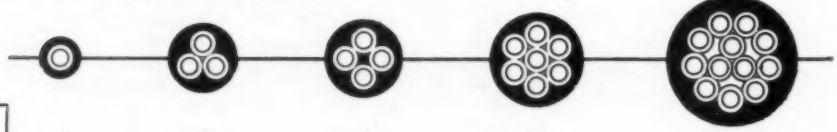

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WATER POWER

A technical journal devoted to the study of all aspects of Hydro-Electric Development

Standardisation of Distribution Equipment

THE hydro-electric engineer has certain advantages denied to his brethren who are concerned with the generation of power from fossil fuels or with the operation of nuclear power stations. In these two fields of activity, the fundamental problems of nature continually obtrude, with fresh discoveries demanding attention, new limits to temperatures and pressures posing new operational problems, and new materials and techniques requiring study and thought. There is little that is static about the life and activity of engineers in these changing fields, whereas the hydro-electric engineer can harness a very high proportion of the energy in his "raw material"—falling water—and can then feel that his plant will run, with undiminished efficiency and almost no operational attention, for many years to come. He does not have to consider the complete replacement of his plant every fifteen years or so because new developments, arising out of advances in physical science, have made the existing equipment obsolescent and uneconomic.

Given this advantage, he is therefore free to devote himself to the two remaining aspects of electricity supply: the efficient transportation of the energy from the point of generation to the place of use, and the reticulation of the supply services to the points of actual consumption.

In the first of these two fields it can be said that the water-power countries of the world lead in transmission progress. Sweden is outstanding in this sphere, and her example in pioneering both 400 kV a.c. lines and high voltage d.c. transmission has been admired throughout the electrical world. Advanced transmission techniques have been evolved in France, Italy, Switzerland and the U.S.S.R., all in connection with the hydro-electric part of the power-generating installations in those countries.

In the second field the efforts of hydro-electric engineers, unhampered by the need for continual replacement of generating plant, might well show to better advantage than has been the case in many parts of the world. In the low voltage distribution and utilisation aspect of electricity supply, one of the first needs is for the highest possible degree of standardisation, both within a single country and, if possible, throughout wide areas of the world. Only by standardising voltage, frequency, and system of supply can manufacturers build up ranges of standard components which can be made cheaply, so that electrical equipment in consumers' premises can be made freely available in all those parts of the world where international trading can take place.

In Great Britain a standard voltage of 240 V a.c. has been established, while voltages between 110 and 220 are common on the Continent. This postulates at least several types of motor winding, several types of resistance element, and several types of lamp filament, where one would suffice for complete interchangeability, thus reducing manufacturing costs. Taking the world as a whole, voltages between 100 V and 260 V are in common use, making for a useless multiplicity of ranges of equipment.

The single-phase system of rural supply, using two wires, is applicable in vast areas of the Continent and America, and thus the use of motors on smallholdings and farms involves certain difficulties and the provision of non-standard types, limited in power and relatively costly for any size above a fraction of a horsepower. In other parts of the world, all new rural wiring is on the three-phase system, so that the cheap, reliable and highly adaptable squirrel-cage motor can be employed even on the smallest farm.

The safety regulations vary considerably between countries and even within a given country. In a recent document on Rural Electrification published by the Economic Commission for Europe the following paragraph appears: "The co-existence of statutory safety regulations and supplementary non-compulsory provisions (in many countries) is a source of danger, since observation of the latter, though often essential, depends on the watchfulness of the supply companies and the professional integrity of electrical contractors. This situation is difficult to avoid in highly electrified

countries, where the regulations are of later date than the installations, and must take account of established rights and current practice. The result is that practices which it would be safer to prohibit are merely discouraged. On the other hand, a country just starting on rural electrification can avoid this difficulty and introduce completely compulsory regulations taking account of the experience gained elsewhere. It may be noted that such regulations, by forcing a choice between certain systems of equal efficiency, could facilitate standardisation of the equipment used."

A lengthy catalogue of anomalies in the practices concerning the distribution of energy as between one locality and another could easily be compiled; indeed, this same ECE document lists many of them.

It is surely time for the same degree of international co-operation on electrical characteristics, safey standards and other similar features of low-voltage equipment to be evolved as those which have already been achieved in a number of other aspects of commercial life. For example, telephone communication throughout Europe or America, or between them (with the aid especially of the new trans-Atlantic cable) has implied the acceptance of certain international standards. Air navigation has meant that the electronic and other equipment on airfields has had to be to some extent standardised on an international basis. For very many years railroad transportation across frontiers has meant the acceptance of internationally agreed standards of safety and technical equipment.

There have been many proposals for customs unions and economic groupings among European countries to facilitate all kinds of trade. There are many international bodies (and in particular the International Electro-technical Commission) which have already achieved a certain level of electrical standardisation on a world scale; but their efforts so far have been aimed rather at larger, specialised items of equipment than at the domestic and small industrial level, where it appears to be needed so much more.

In hydro-electric countries, the power engineer frequently occupies a much stronger position than does his opposite number in countries where there is a degree of competition between sources of energy—gas, coal, oil and electricity. He is the sole purveyor of energy in so many cases: he provides the power, transports it in bulk, and retails it to each consumer, often providing wiring and equipment sale facilities as well. He is well equipped to take the lead in evolving international standards in low voltage equipment.

Conference on Soil Mechanics

DETAILS have now been issued about the Fourth International Conference of the International Society of Soil Mechanics and Foundation Engineering, which is to be held in London from the 12th to the 24th August this year. The Society, whose President is Professor Karl Terzaghi, Professor of the Practice of Civil Engineering, Harvard University, has over 3,000 members from 29 different countries, though attendance at the Conference is not restricted to members.

Soil mechanics, or the "scientific study of soil as an engineering material" is a comparatively new science, dating largely from Professor Terzaghi's own investigations in the 1930s. Today Great Britain and other countries have many laboratories for studying the subject, some of them run by firms of civil engineering contractors.

Former conferences were held at Cambridge, Massachusetts, Rotterdam and Zurich, and were attended by upwards of 800 delegates. Owing to growing interest, however, preparations are being made to accommodate an even larger number for the London conference.

For many of the delegates and their wives it will be their first visit to this country, and arrangements have been made for tours to various parts of Great Britain to show something of the scenery, historic places, and industrial life.

The Chairman of the organising Committee is Dr. W. H. Glanville, Director of the Department of Scientific and Industrial Research, Road Research Laboratory. The Council of the Institution of Civil Engineers have placed the Institution building at the disposal of the Society for the technical programme of the Conference, and full details and application forms to attend can be obtained from the Society's Secretary, Mr. A. Banister, O.B.E., The Institution of Civil Engineers, Great George Street, London.

I.A.H.R. Hague Conference Proceeding

THE International Association for Hydraulic Research has now published the full proceedings of the conference held at The Hague from August 31 to September 6, 1955. Publication is in four volumes, each devoted to the papers under one of the four main subject headings into which the papers were grouped.

The first group discusses tidal hydraulics and tidal models and consists of 15 papers from eight countries. These papers include two theoretical contributions, two comparing field observations with theory, three discussing tidal-model technique, four describing actual models of large size, and three investigating special phenomena.

The second group, of 23 papers from 10 countries, is devoted to instrumentation, and may be conveniently divided into papers covering measuring instruments and those covering controlling instruments. A significant tendency is the extent to which electronic equipment is being adopted for instrumentation; no less than 16 papers describe instruments involving electronic aid.

Twenty-seven papers from 13 countries form the third group dealing with the hydraulics of outlet works, and cover the general theory and design of outlet works, shaft spillways, siphon spillways and siphons, weirs, downpull forces on gates, scour and dissipation of kinetic energy, and miscellaneous problems.

The final section comprises 26 papers from 13 countries and covers miscellaneous subjects. Questions involving flow in channels and bedload transportation loom largely in this section, although there are papers on stoplogs, flow over dams, and other subjects.

The first volume also contains the opening address by Mr. J. Algera, the Netherlands Minister of Transport and Waterways, and at the beginning of each volume is an excellent summary and analysis of the papers contained therein. The Minister's address, the summaries of the papers, and general information

about the conference are given in French and in English in adjacent columns. The papers themselves are in the one language or the other according to that in which they were presented to the conference.

This was the Sixth Congress of the Association and was attended by 183 participants from 29 countries under the chairmanship of Dr. Lorenz G. Straub. As announced in these columns last month, the Seventh Congress will be held in Lisbon from July 25 to 31 of this year.

New Zealand Hydro Report

NEW ZEALAND'S high future potential as a customer for hydro-electric plant is again emphasised in the Annual Report recently published by Mr. W. S. Goosman, the Minister in charge of the State Hydro-Electric Department. New Zealand's total hydro-electric capacity has already exceeded one million kilowatts, and it will have to grow to three to four million kilowatts within the next 20 years.

Present proposals are that hydro-electric resources will continue to be developed in both islands, together with further geothermal development in the North Island, and at the same time investigating the possibility of laying a cable across Cook Strait. Such a cable would confer many benefits, for not only is there a high power potential in the South Island which is badly needed in the North Island, but the two islands have their rainy seasons at different times. In fact, a study of the hydrology of the two islands indicates that if the present separate electrical systems could be interconnected the drawdown on water storage could be greatly reduced. Nuclear power seems to be a proposition for the more distant future, provided the Cook Strait cable proves practicable.

During the next ten years the North Island will increase its capacity by one million kilowatts and the South Island by 370,000 kW. The latter will be represented chiefly by the output from the Benmore project, work on which is being started this year and which will be comparable in size to Roxburgh.

The capital expenditure for New Zealand hydro installations, including investigations and surveys, amounted last year to £13,521,240. It is considered unlikely that the necessary power could be provided by steam stations fired by coal, which would waste an important local asset. Mr. Goosman points out that when it is appreciated that financial provision for electrical generation and distribution will involve about £500 million over the next 19 years, the importance of choosing the right course becomes evident.

Pumped Storage Investigations

THE advent of nuclear power in Scotland has encouraged hopes for a major expansion of hydro-electric generation through the operation of pumped storage projects. The North of Scotland Hydro-Electric Board has already surveyed possible sites for such installations, two near Loch Lomond and one at Loch Awe. This application is being given serious consideration and links up with the announcement by the South of Scotland Electricity Board which anticipates the use of nuclear generated power to pump water to storage levels during off-peak periods.

Pumped storage is not new to Scotland; as long ago as 1922 a Walkerburn tweed mill installed a plant which gave 50 hours' service each week. Pumped storage was also advocated for an earlier Loch Sloy project but failed to find support. The necessary conditions for successful operation of pumped storage would be a sufficiently large volume of low-level water with a limited distance between the higher and lower levels. Loch Lomond, Loch Ness and Loch Awe all constitute potential low-level sources. Loch Sloy might provide a suitable higher level to Loch Lomond and the Burn of Mar has also been suggested, both sites being described in the Board's last report as "very favourable for pumped storage." Loch Awe could also provide an attractive site with Cruachan station becoming a pumped storage installation. It is stressed that present work is still exploratory and that considerable further work remains to be done before formal proposals can be put forward.

Progress in South Italy

SOUTHERN Italy (Sicily and Sardinia excluded) is a rather depressed area of 73,300 sq. km. and 12,500,000 inhabitants with very difficult oro-hydrographic conditions and consequent poor industry and communication development. The electric power output in this area in 1955 was 3,760 million kWh, of which 3,440 millions—i.e. 90%—were of hydraulic origin. The consumption rate per head of population was, therefore, 327 kWh, while in northern Italy it neared 1,300 kWh. The average production increase in southern Italy in 1955 was rather low as compared to 1954—about 4%—the average increase in Italy being 7·2%. This was partly due to the scarce and irregular precipitations in 1955, which affected particularly the storage and outlet processes of reservoirs. Notwithstanding the increased capacity of storage, the maximum average storage was more than one quarter lower than in the previous year.

The hydrological situation remained unchanged during the first two months of 1956, after which it began to improve. This improvement coincided with the putting into operation of some new and important plants at the end of 1955 and resulted in a substantial rise in output in the first six months of 1956 in comparison with the previous year: 2 milliard 300 million kWh were produced over this period, while in the first six months of 1955 only 1 milliard 800 million kWh were produced. The difference in absolute value is half a milliard kWh, i.e. a percentage increase of 26·5%. No official data have been obtained for the second half of 1956; yet, from unofficial information we may gather that a substantial increase occurred over that period too. Assuming the value of the 1946 production to be equal to 100, the output in 1955 was 306, while 1956 production should be about 390, which represents a considerable rise.

The progress achieved was due, at least in part, to the vast programme adopted in recent years with a view to promoting the economic advance of the area. In 1951 the "Cassa del Mezzogiorno" was established by the Italian Government. Through this technical-financial Institute the Government has planned an investment of 1,000 milliard Italian Lire for public-utility work in 10 years (about £550 million). 500 milliards are destined for reclamation, irrigation and aqueduct works. On February 12, 1955, a bill was passed providing for the establishment of another

fund to be used on new industrial undertakings or for the enlargement and modernisation of the old ones.

Among the South Italy plants put into operation in 1955 were the Montorio al Vomano plant of the Società Terni, and the Mucone Secondo Salto plant of the Società Meridionale di Elettricità. They are the two most important Italian plants put into operation in the course of the year.

Montorio is the third step of a large scheme developed in Abruzzo, the Vomano scheme, deserving a special mention for its characteristics. Besides producing a total of 700 million kWh, it discharges a noticeable compensation and regulation function in Italian production. The scheme is developed in three steps between 1,300 m. and 100 m. above sea level. The first step comprises a 150 million cu. m. reservoir at Campotosto (an enlargement to 325 million cu. m. is prospected) which is fed both by its natural drainage area and by the water of the lower-lying river Vomano, which is stored in the smaller Provvidenza reservoir. The water of the Provvidenza reservoir is pumped to the Campotosto reservoir through the Provvidenza underground power and pumping station where a total capacity of 100,000 kW is installed. Downstream of this power station a 14 km. tunnel conveys the water of the right-bank tributaries of the Vomano to the S. Giacomo underground power station, which constitutes the second step of the scheme. With its three sets reaching a total capacity of 210 MVA, it is one of the largest underground power stations in Italy. Downstream from S. Giacomo begins the step recently finished. The new Piaganini reservoir on the Vomano allows the regulation of the water discharged by the S. Giacomo power station. From the reservoir a tunnel 14 km. long conveys the water to the Montorio power station after receiving also the water of adjacent drainage areas through a system of collecting works still under construction. The Montorio power station is equipped with three Francis and two Pelton sets, reaching the total capacity of 120,540 kW.

Among the plants under construction in South Italy are the Bussento Secondo Salto plant of the S.M.E., the Angelo sul Sangro plant of the A.C.E.A., and the enlargement and completion of some existing plants, such as the Venamartello plant of the U.N.E.S. The total estimated production of the plants under construction is 600 million kWh approximately.

Since the total estimated potential in South Italy is about 7,500 million kWh, the potential already exploited or under exploitation is slightly higher than half the available total.

Rocky Reach Turbine Contract

AN order for hydraulic turbines valued at well over 11 million dollars has been awarded to the S. Morgan Smith Company, of York, Pennsylvania, by the Public Utility District No. 1 of Chelan County, Washington. The contract includes seven 140,000 h.p. Smith-Kaplan turbines with governors, to be installed in the Rocky Reach hydro-electric power project on the Columbia River. This is the largest single order ever received by the York firm.

The site of the plant is about nine miles north of Wenatchee, Washington, and is immediately downstream from the Chief Joseph power project for which S. Morgan Smith is building six 100,000 h.p. vertical Smith-Francis type turbine units. Engineers for the Rocky Reach project are Stone and Webster Engineering Corporation, of Boston, Massachusetts.

The 280 in. runners of the Rocky Reach units will be installed vertically in concrete spiral cases and will operate at 90 r.p.m. under a rated head of 92 ft. Shipments are scheduled to begin with the embedded parts during the summer of 1959 and will be completed about two years later. Field construction on the project is now in progress.

Techniques for Hydraulic Machinery Research

IN the leading editorial article in our September 1956 issue we commented on the D.S.I.R. annual report "Mechanical Engineering Research," which included a description of the equipment at East Kilbride Hydraulics Laboratory. Dr. S. P. Hutton, who is in charge of the laboratory, recently read an absorbingly interesting paper, "Techniques for Hydraulic Machinery Research," before the Institute of Engineers and Shipbuilders in Scotland, in which he explained the stringent requirements underlying the design of the equipment.

These requirements revolved round the exceptionally high standard of accuracy considered to be necessary in order to obtain reliable information from model experiments. The view was taken that unless accurate and repeatable measurements could be made, small differences between various designs could not be detected and the possibility of improvement would be lessened. For instance, one target was to measure the efficiency of hydraulic machines within a probable error of 0·25%, which meant that flow, head, rotational speed, and torque would have to be measured with an error of less than 0·1%.

The special designs of apparatus to control and measure these quantities to this exceptionally high standard of accuracy formed the main subject matter of Dr. Hutton's paper. Many of the designs are the outcome of original work on the part of the laboratory staff, and are of great interest.

Roxburgh Generators

IN the article on Roxburgh, written for us by a New Zealand contributor and published in our February issue, we deeply regret that the name of the manufacturer of the alternators was given incorrectly. Actually the four 44,444 kVA 11 kV machines were supplied by The British Thomson-Houston Co. Ltd., Rugby, England. These machines run at 136·4 r.p.m. and have a runaway speed of 252 r.p.m. Each alternator weighs 363 tons and has an overall diameter of 29 ft., and the design had to allow for the machine to be broken down into comparatively small parts for transport.

Roxburgh to be Completed

TENDERS are to be called for the supply of four generators and turbines at the Roxburgh hydro-electric scheme, described in our February issue, which will bring the station to its full capacity of 320 MW. At the same time, a new high-voltage line will be built to enable Roxburgh's full output to be available as soon as it is reached.

The Slope-template Method for some Hydraulic Problems

W. E. Blackmore, A.M.I.C.E., A.M.I.W.E., proposes a new graphical method to replace laborious step-by-step computations in problems in which two functions are interdependent

IN a previous article in this journal* the author described a graphical method, using line diagrams, for dealing with certain problems of hydraulics involving storage. This article presents another graphical method to deal with some of them. Generally the problems to which the method can be applied are those in which two functions of the same parameter t, namely X and Y, are related by the condition that, as progress is made along the axis of the parameter t the rate of change of Y at one point is directly related to the difference between X and Y or vertical distance between the two curves at that point, i.e. $\frac{dY}{dt}=f(X-Y)$. Given the curve representing the variation of X, the slope-template method allows the immediate plotting of the curve of Y.

The Slope-Template

The method involves the use of a template which will be referred to as the Slope-Template. It is a plotting device consisting of a rectangular piece of transparent celluloid the lower edge of which is a straight edge AB with a "step" at A acting as a pencil stop. The face of the template should be frosted so that curves can be drawn on it in pencil. The plotting procedure will be described by means of examples of the various applications of the method.

Fluctuations in a Tidal Basin

This is the simplest of the cases to which the slope-template method applies. Assume a vertical-sided basin connected to tidal waters by an orifice and that it is desired to determine the basin curve. The rate of flow in and out of the basin at any instant, i.e. the rate of rising or falling of the level in the basin, is directly related to the difference in level between the basin and the tidal water, the relationship being the law of flow through an orifice. If the tide level and basin level are plotted against time on the same graph, the slope of the basin curve at any instant will be related to the vertical distance between the basin curve and the tidal curve at that instant. In the following example the tidal curve is given in Fig. 1 as well as a starting point O of the basin curve at a certain time, the other data being: basin area, 170,000 sq. ft.; orifice capacity, $Q=30\ H^{\frac{1}{2}}$ cusecs (H=difference in level between basin and tide).

Assume that the plotting of the basin curve has reached point O_1. The difference in level between O_1 and the tidal curve at point P_1 is 8·0 ft., and with this head the inflow into the basin would be 85 cusecs or 1·8 ft. rise of level per hour. Now place the slope-template with its point A over O_1 and its straight edge AB set to a slope corresponding to a rate of rise of 1·8 ft. per hour; then mark on the template a point over P_1 seen in transparence. This is one point of the curve which has to be drawn on the template to do the plotting; other points are obtained by rotating the template round O_1, setting the edge AB to other slopes corresponding to various rates of rise in the basin, and marking on the template the corresponding heads measured on the vertical of O_1 seen in transparence. The points are joined together to give a curve which will be referred to as the "template curve." A curve such as this will be needed for each new problem on which the template is used. Incidentally it should be noted that this curve, being plotted to co-ordinates which are not rectangular, will not have the familiar shape it has in rectangular coordinates. The coordinates of the slope-template are like polar coordinates but with the value of the trigonometrical tangent replacing the angle for one of the parameters. The tangent AZ to the template curve at point A will be referred to as the "zero line."

Having thus prepared the template the plotting is

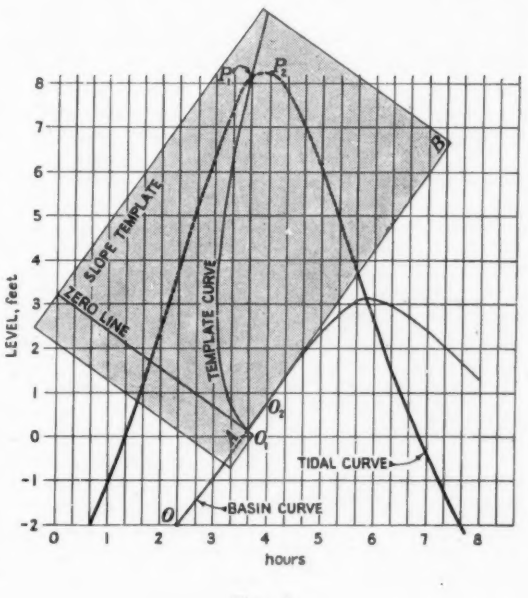


Fig. 1

*"Line diagrams for problems of storage" by W. E. Blackmore, WATER POWER August and September 1952, pp. 299 and 355.

carried out as follows. It is done on squared paper with levels as ordinates and time as abscissa so that the vertical lines mark time intervals. Place the pencil point on point O_1; place the slope-template with A against the pencil point; rotate the template, using the pencil point as pivot, until the template curve comes over point P_1 on the tidal curve seen in transparence through the template; draw a line along the straight edge to the next time interval and obtain O_2; hold the pencil on O_2 and slide the template until its point A is again touching the pencil point; rotate the template to bring the template curve over P_2, draw the line to the next time interval and so on. When the tidal and basin curves cross each other the template is reversed and the plotting continued with the tidal curve now below the basin curve. The length of time intervals has no particular significance; the shorter it is the more will the plotted line be like a smooth curve and less like a polygon. It can be varied as one goes along, longer intervals being taken when the curve is almost straight and shorter ones when it takes a sharp curvature.

Reservoir Mass-Curves

This is one aspect of the routing problem in reservoirs. Here the rate of outflow is directly related to the volume held in the reservoir. Expressed in the general terms of application of the slope-template stated at the beginning of the article one could say that the rate of increase or decrease of the accumulated volume of outflow (i.e. the rate of outflow) is directly related to the difference between the accumulated volume of inflow and the accumulated volume of outflow (i.e. the volume held in the reservoir). Graphically it means that the slope tan α of the outflow mass-curve (Fig. 2) at a particular instant is directly related to the vertical distance O_1P_1 between the inflow mass-curve and the outflow mass-curve. The relationship is dependent on the volume/discharge curve of the reservoir outlet and the water area of the reservoir. In fact, in a reservoir with vertical sides, or in one which can be assimilated to a vertical-sided reservoir over the range of levels involved, the scale of volumes can be replaced by one of feet of level and the difference between the two curves will represent the reservoir level. In the example dealt with below it is assumed that the inflow mass-curve is given as well as an initial point of the outflow mass-curve, the other data being: reservoir area, 10 million sq. ft.; outlet capacity, $Q=87H^{3/2}$ cusecs.

For plotting, a curve is drawn on the template such that, when the straight edge AB is set to a slope representing a certain rate of outflow, the distance O_1P_1 (Fig. 2) represents the corresponding head or volume held in the reservoir. The plotting is then carried out as already described and the outflow mass-curve obtained.

Reservoir Hydrographs

The slope-template method can also be applied to the plotting of the hydrograph of outflow from the hydrograph of inflow instead of mass-curves. The reasoning is as follows (Fig. 3): at any instant the rate of increase of the outflow, represented by tan α, is related to the difference O_1P_1 between inflow and outflow. The greater this difference the quicker does the outflow increase; where the difference is nil, i.e. where the inflow and outflow hydrographs intersect, the rate of increase of outflow is nil and the outflow hydrograph has a summit. The relationship again depends on the area of the reservoir and the discharge curve of the outlet. In this case the curve which has to be drawn on the template is a curve giving the rate of increase of outflow against difference between outflow and inflow. If the stage/discharge or volume/discharge curve of the outlet were a straight line, with a constant rate of increase of flow per foot of level, a single curve would suffice on the template. In the general case where the rate of increase of flow varies with the value of the flow a series of curves will be needed on the template, one for each of several rates of outflow, and the appropriate curve used in the course of plotting according to the value of the outflow reached at any instant.

For the example dealt with here five curves were drawn on the template (Fig. 3) for outflow values of 10, 20, 30, 40 and 50 cusecs; their construction will be explained later. The other data were: reservoir

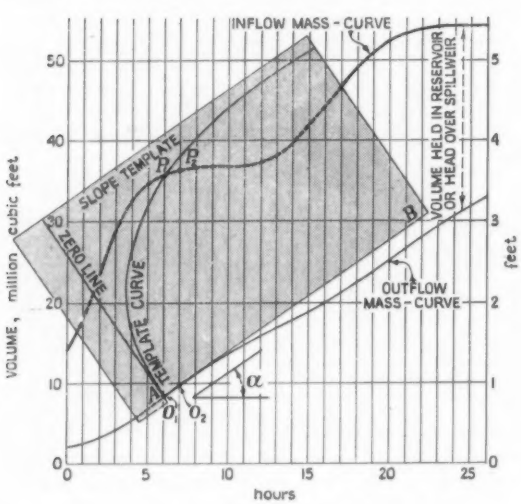


Fig. 2

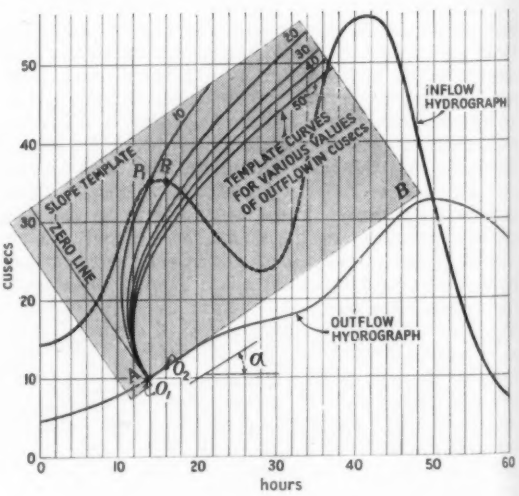


Fig. 3

area, 2 million sq. ft.; outlet capacity, $Q=10H^{3/2}$ cusecs.

Given the inflow hydrograph and the initial value of the outflow, the plotting of the outflow hydrograph is carried out as described previously, using at each step of the plotting the template curve appropriate to the rate of outflow reached or a curve mentally interpolated between them to suit intermediate values of the outflow. When the outflow hydrograph crosses the inflow hydrograph the template is reversed and the same procedure continued.

The construction of the template curves will be explained by giving the reasoning applicable to the curve for 30 cusecs as an example, the data, as before, being reservoir area, 2 million sq. ft. and the outlet capacity $Q=10H^{3/2}$ cusecs.

Rate of increase of outflow with rising level:

$$\frac{dQ}{dH}=10\times\frac{3}{2}H^{\frac{1}{2}}=10\times\frac{3}{2}\left(\left(\frac{Q}{10}\right)^{\frac{3}{2}}\right)^{\frac{1}{3}}=10\times\frac{3}{2}\left(\frac{Q}{10}\right)^{\frac{1}{3}}$$

$$\frac{dQ}{dH}=15\left(\frac{30}{10}\right)^{\frac{1}{3}}=\quad 21{\cdot}7 \text{ cusecs per ft.}$$

Find the time T it would take, at that rate of increase and for an excess of inflow over outflow equal to R, for the increase in outflow to become equal to R:

Rise in level: $\frac{RT}{A}$ (A=reservoir area)

Increase in outflow: $21{\cdot}7\,\frac{RT}{A}$

Make this increase equal to R: $\frac{21{\cdot}7\,RT}{A}=R$

Therefore: $T=\frac{A}{21{\cdot}7}=\frac{2{,}000{,}000}{21{\cdot}7}$ seconds

$T=25{\cdot}6$ hours

Draw on graph paper (Fig. 4) a vertical construction line at a distance equivalent to 25·6 hours from the origin. Hold the pencil point on the origin, place the template with its point A against the pencil point and rotate it until its straight edge cuts the vertical line at, say, 13 cusecs and mark on the template the 13 cusecs point on the vertical of the origin seen through the template. Repeat for other values of the flow, and join the points on the template to form a curve which will be the template curve appropriate to an outflow of 30 cusecs. For the other rates of outflow, namely 10, 20, 40 and 50 the values of dQ/dH would be 15·0, 18·9, 23·8 and 25·7 cusecs per ft. and the distances to the corresponding vertical construction lines 37·0, 29·4, 23·3 and 21·7 hours. With these lines the same construction as before will give the other four template curves for 10, 20, 40 and 50 cusecs of outflow.

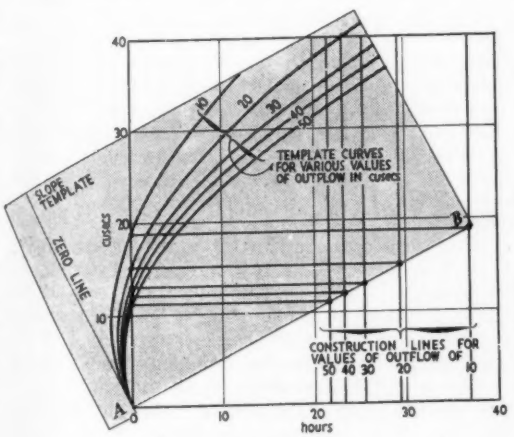


Fig. 4

If the outlet curve is not one which lends itself to being put into mathematical form and derivated, the determination of the values of dQ/dH is done graphically. If the reservoir is not one which can be assimilated to a vertical-sided one of constant area, the computation is done with an outlet rating curve plotted as outflow against reservoir volume instead of level.

Rainfall/Run-off Relationship

This problem is no longer one which obeys well-defined formulae. However the theory frequently put forward which likens the rainfall/run-off relationship to that of reservoir inflow/outflow seems to give the best fit to observed data. It is also the one which is of the most practical use for the problems normally encountered. It is, therefore, the theory which will be used here with the introduction of three additional factors, namely:

(a) An allowance for losses (evaporation, etc.) which will be assumed proportional to the rainfall, an assumption which is more convenient and as tenable as any other considering the margin of error to which all rainfall/run-off theories are subject. This allowance will be made by using on the graph a scale for rainfall and a different one for run-off, the difference representing the losses.

(b) A fixed delay between the time of rain falling and the time of its appearing as inflow into the fictitious reservoir represented by the catchment. This is allowed for, on the graph, simply by a displacement along the time scale of the rainfall curve in relation to the run-off curve.

(c) A "drag" factor representing the brake applied by the catchment on the variation of run-off from one day to the next or, generally, from one time interval to the next. This factor, in fact, is like that which would occur in a reservoir formed by a long canal such that there would be an appreciable gradient towards the outlet. This notion of drag is believed to be a new addition to the reservoir theory of rainfall/run-off relationship. It is taken into account in the plotting as described below.

On the basis of similarity with reservoir inflow/outflow the plotting could be done either using rates of rainfall and run-off as described under Reservoir Hydrograph or by using their mass-curves. The latter (see Reservoir Mass Curves) is the more appropriate as the effect of rainfall on run-off is essentially a cumulative one. The plotting will therefore be done basically as described previously. In this case, however, the mass curves will be plotted as cumulative departure from a fixed rate as this produces a more manageable graph. It means that, in periods of no rainfall or zero run-off the line slopes downwards at a slope corresponding to the fixed rate instead of being horizontal and, on the template, the zero line is also inclined in relation to the straight edge instead of being normal to it. The loss and delay factors make no difference to the plotting once they have been allowed for in the scales of the graph.

The drag factor is taken into account by means of a slot and curve on the template which are used as

follows during plotting (Fig. 5). The object is to apply at each step of the plotting a reduction to the change of slope. To do this each chord of the run-off curve drawn along the straight edge AB of the template during the plotting, say $O_1 O_2$, is extended backwards along the edge CD of the slot which is in line with it. When the next plotting step is taken and the template is moved along to O_2 and rotated to bring the template retention curve over the rainfall mass-curve at P_2, the change of slope is indicated by the intersection M of the backward extension in the previous step with the arc EF. This intersection is followed visually along the "spokes" drawn on the template to point N on the drag curve and the template is rotated back to bring this point N over the backward extension; the chord $O_2 O_3$ is drawn along the straight edge AB to the next time interval, with a backward extension drawn along CD, and so on.

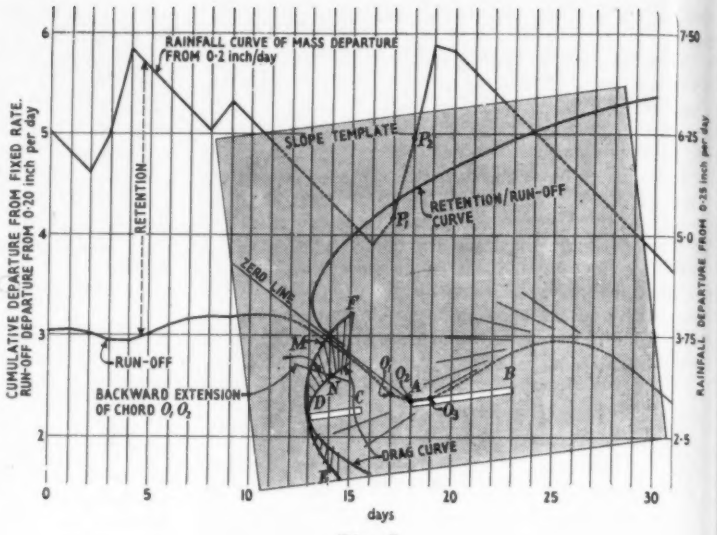

RAINFALL CURVE OF MASS DEPARTURE FROM 0·2 inch/day
SLOPE TEMPLATE
RETENTION
RETENTION/RUN-OFF CURVE
ZERO LINE
RUN-OFF
BACKWARD EXTENSION OF CHORD $O_1 O_2$
DRAG CURVE
CUMULATIVE DEPARTURE FROM FIXED RATE. RUN-OFF DEPARTURE FROM 0·20 inch per day
RAINFALL DEPARTURE FROM 0·25 inch per day
days

Fig. 5

The retention and drag curves on the template as well as the delay and percentage loss are derived from a run of simultaneous rainfall and run-off records which it is necessary to have. From these records mass-curves of rainfall and run-off are plotted one below the other, the latter at a scale which makes the total run-off equal to the total rainfall between two dates on which the rate of run-off had the same value. The delay is also determined as the displacement of one curve in relation to the other to make the peak run-off fit maximum retention. The retention curve is then determined by taking corresponding values of retention and run-off when the run-off curve is fairly straight and the effect of drag negligible. Lastly the drag curve is determined from those stretches where there is a rapid rate of change, i.e. where the curvature of the run-off curve is pronounced, and the drag effect is appreciable. A certain amount of trial and error is necessary before mutually consistent values of the factors are determined.

Flow in Open Channels

Consider a portion of rectangular channel of sufficient width so that the friction on the sides can be ignored. In this channel the energy head, measured above the invert, is given by:

$$E=d+\frac{v^2}{2g} \qquad \text{where } d=\text{depth},\ v=\text{velocity} \qquad ..(1)$$

If Q is the flow per ft. width of channel:

$$E=d+\frac{Q^2}{2gd^2} \qquad ..(2)$$

To simplify the writing out of the subsequent formulae the constants are grouped into a factor $K_1=\frac{Q^2}{2g}$ so that

$$E=d+\frac{K_1}{d^2}$$

The friction gradient s, is assumed to be given by Manning's formula:

$$v=\frac{1{\cdot}486}{n}\,m^{\frac{2}{3}}\,s^{\frac{1}{2}} \qquad \text{where } n=\text{friction coefficient}$$
$$m=\text{hydraulic mean depth}$$

Expressed in terms of s and taking $m=d$ this expression becomes:

$$s=v^2\,\frac{n^2}{1{\cdot}486^2}\,\frac{1}{d^{4/3}}$$

$$s=\frac{Q^2}{d^2}\,\frac{n^2}{1{\cdot}486^2}\,\frac{1}{d^{4/3}} \qquad ..(5)$$

Grouping together the constants into a factor $K_2=\frac{Q^2\,n^2}{1{\cdot}486^2}$

$$s=\frac{K_2}{d^{10/3}} \text{ or } d=\frac{K_2^{3/10}}{s^{3/10}} \qquad ..(6)$$

$$E=\frac{K_2^{3/10}}{s^{3/10}}+\frac{K_1 s^{6/10}}{K_2^{6/10}} \qquad ..(7)$$

E, the energy head, is, in effect, the difference between two functions X, the altitude of the invert, and Y, the altitude of the energy line. This is seen more clearly if the graph is looked at upside down (Fig. 6), the invert line being above and the energy line below. The parameter t is the distance in feet along the course of the waterway so that the hydraulic gradient, s, is $\frac{dY}{dt}$; therefore we have: $\frac{dY}{dt}=f(X-Y)$. The conditions are as stated in the first paragraph of this article and the plotting of the energy line is a problem which comes within the scope of the slope-template.

The slope-template is prepared by plotting on it the curve corresponding to the function of slope against energy head. This is done by setting the straight edge AB of the template to various slopes (natural or distorted according to the scales adopted for plotting the graph) and marking the corresponding values of the energy head E (obtained by formula (7)) on the vertical, seen in transparence, of the point on which the "step" of the template is held. The energy head reaches a minimum value corresponding to the critical depth. Two examples are given below showing how the energy line is plotted with the template.

The first example is the case of a spillway ski-jump (Fig. 6). The hydraulic gradients involved are comparatively steep and therefore the graph is

plotted to "natural" scales, i.e., to equal vertical and horizontal scales. Where the slope of the invert itself (as distinct from the hydraulic gradient) is steep the invert has been drawn "developed," i.e. the slope length between two points has been laid out horizontally, the difference in level between the two points remaining the same. This is to allow for the fact that the friction loss given by the formulae is a loss per foot of surface traversed and not per foot of horizontal distance. For simplification the effect of centrifugal pressure due to the curvature of the invert has been ignored.

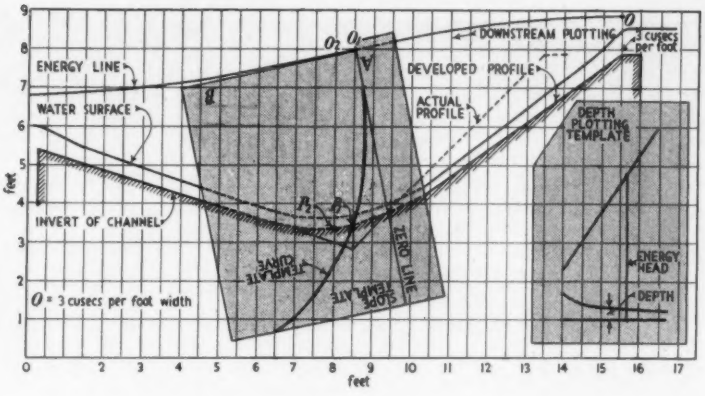


Fig. 6

The data are: Q=3 cusecs per foot width
n (friction coefficient)=0·013

The values given in Table I were computed on the basis of formula (7) and from these the curve on the template was plotted.

TABLE I

s	E ft.	s	E ft.
1 in 2	7·49	1 in 10	3·02
1 in 3	5·91	1 in 20	2·12
1 in 4	5·00	1 in 50	1·41
1 in 5	4·43	E min.	0·98

A starting point O is known, namely the energy head over the spillweir crest which forms a hydraulic control and where, therefore, the energy is equal to E min. The plotting is done with the graph held upside down for convenience. At any point O_1 the template is held as previously described, rotated to bring the template curve over P_1 on the invert line, the energy line drawn to O_2, the template moved on to O_2 and so on. This plotting produces the energy line only. If the line of water surface is also required this has to be drawn by a separate operation by plotting point by point (not with the slope-template) the water depth corresponding to each value of the energy head. To facilitate this a simple tracing-paper template (shown in the right hand corner of Fig. 6) can be made up with a horizontal datum line, a straight line for the energy head and a curve for the depth, the last two being computed one from the other on the basis of formula (2). This template is placed successively at various points along the graph in such a way that, on any vertical, the datum line intersects the invert and the template energy line intersects the plotted energy line; the depth can then be pricked through.

The second example (Fig. 7) deals with flatter gradients and the plotting is done to distorted scales. The example has been selected to show a case where the flow changes from shooting flow to tranquil flow. The data are given in Table II.

TABLE II

Q=12 cusecs per foot width n (friction coefficient)=0·017			
s	E ft.	s	E ft.
1 in 20	4·76	1 in 282	2·48 (E min.)
1 in 50	3·29	1 in 500	2·54
1 in 100	2·73	1 in 1000	2·80

The plotting is started from the upstream control point, in this case a sluice gate, and proceeds downstream as the flow is shooting flow. The figure shows the template in position for the plotting at chainage 600 ft. A stage is eventually reached near chainage 300 ft. where one " runs out of head " and the plotting can go no further. It is an indication that there will be a hydraulic jump about there downstream of which the flow will be tranquil. Therefore the plotting has to be resumed starting from the downstream control point, in this case a weir, and working upstream. The two curves meet near chainage 300 ft. and the jump would be near their intersection. Its more exact location would be given by the intersection of the lines representing the momentum function:

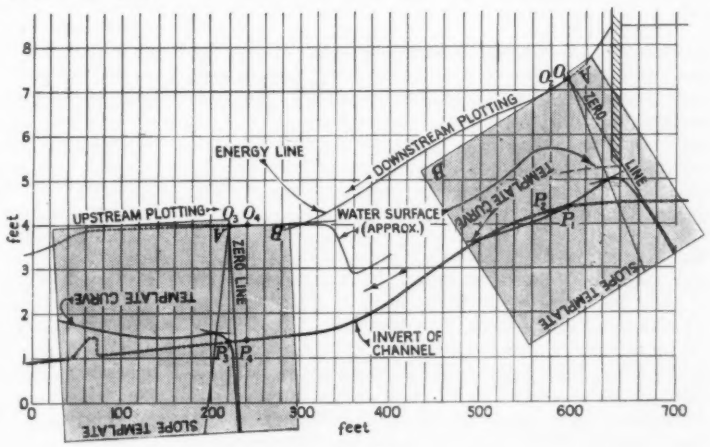


Fig. 7

$M=\frac{Q^2}{gd}+\frac{d^2}{2}$ for the shooting and tranquil flow but this was not done on the figure as not being an operation coming within the scope of the template.

To make it possible to do the plotting working either upstream or downstream two templates were used for the example dealt with in Fig. 7, with their plotting edges *AB* facing opposite ways. Another method would be to make the template large enough so that the template curve can be drawn symmetrically on both sides of the zero line *AZ*.

The above examples deal with well-defined rectangular channels. With an irregular river bed it would be necessary to draw on the template an $E=f(s)$ curve for each of a number of cross-sections along the course of the river, and do the plotting as previously described using at each step the appropriate template curve.

The same thing has to be done in the case of a non-parallel rectangular channel, a series of curves being drawn on the template, one for each of the various values of flow per foot of width corresponding to the various widths along the length of the channel.

Conclusion

As stated at the beginning of this article, several of the problems dealt with above could also be dealt with by the line-diagram method previously published in this journal. The choice of method for each problem should take into account the following advantages of each method in relation to the other:

Line diagram: Is quicker to set up and therefore preferable when only one computation has to be made on one set of data; also it leaves on the diagram a permanent record of the working out and therefore allows for an easy independent check.

Slope-template: Once set up, i.e. once the template is made and the curves drawn on it, the plotting is much quicker and more accurate; also the length of the steps can be varied as the plotting proceeds to suit the curvature of the curve being plotted. Therefore it is the most suitable method when several computations have to be made involving the repeated use of the same template.

The Cementation Co. Ltd.

The London offices of The Cementation Company and its various subsidiary companies are now gathered together at one address, "Twenty" Albert Embankment, London, S.E. 11, a handsome new 10-storey block which was designed by T. P. Bennett & Son. The offices of the Mining & Civil Engineering departments occupy the ninth floor, while Cementation (Contracts) Limited are on the eighth, together with the Joint Managing Director's office and the Civil Design & Development sections. The seventh floor is devoted to the Piling, Cementation and Civil Engineering Departments and the sixth to Quickset Water Sealers Limited, Palorit Products Limited, Cementation (Muffelite) Limited, Thermacoust Limited and The Geophysical Prospecting Co. Ltd. The remainder of the building has been sub-let to other well-known firms such as the Mond Nickel Co. Ltd., Imperial Chemical Industries Limited, and the Mobil Oil Co. Ltd. The building was opened to the accompaniment of what might be described as a beneficent flourish of corks on the 10th of December last.

Consultants for Nuclear Station. Although it may appear to be outside our particular field, our readers may be interested to know that Messrs. Kennedy & Donkin, the well-known consulting engineers who have been retained for many important hydro-electric schemes, have been appointed as consultants for the South of Scotland Electricity Board's new nuclear power station in Ayrshire.

The Consolidated Pneumatic Tool Co. Ltd., of London, have announced new plans for the development of their business in the Federation of Rhodesia and Nyasaland. The company has operated in these areas for many years through the agency of Messrs. J. Clack & Co. (Pvt.) Ltd., but the intensive industrial development in these areas has brought a need for similar expansion in the sales and service facilities offered by the Company. Direct representation has therefore been decided upon as the best means of providing the type of technical assistance which the increasing business requires. It is in these circumstances that a new Company has been formed to be known as The Consolidated Pneumatic Tool Company of Central Africa (Pvt.) Ltd., with head offices at 142c, Abercorn Street, P.O. Box 278, Bulawayo, S. Rhodesia. Arrangements have been made, however, for Messrs. Clack & Co., to continue representation in the Salisbury and Ndola territories for the time being, with the assistance of CP technical personnel.

Allweather Paints Limited have sent us a leaflet which deals with a new manufacture, "Pitakote," that is claimed to be easy to apply and to be resistant to acids, alkalis, solvents, fatty acids and heat (110°C) and cold (−40°C).

Soldering Aluminium Cables. In recent years the substantial saving in cost associated with the use of aluminium in insulated cables has been of increasing importance to electrical engineers. In many cases, however, there has been a pronounced reluctance to use aluminium because of the supposed difficulties which might be met in making reliable joints. An instruction book issued by Aluminium Union Limited gives notes on the fundamentals of the problem of soldering aluminium, followed by detailed, illustrated instructions on how to make all the normal types of joint. It covers not only the procedures now generally in use in this country, but also the methods derived from the rather greater experience available overseas. The instructions include methods of soldering aluminium conductors and aluminium cable sheaths. Amongst the appendices is a list of suppliers of all the necessary materials, and comprehensive quick-reference current rating tables for aluminium cables. These are, we believe, the only tables of the kind published so far. They are derived from the C.M.A. tables of current rating factors which are also included. To many engineers these data alone will be of very direct value. This 84 page publication is profusely illustrated and is available gratis on request from Aluminium Union Limited, the Adelphi, John Adam Street, London, W.C.2.

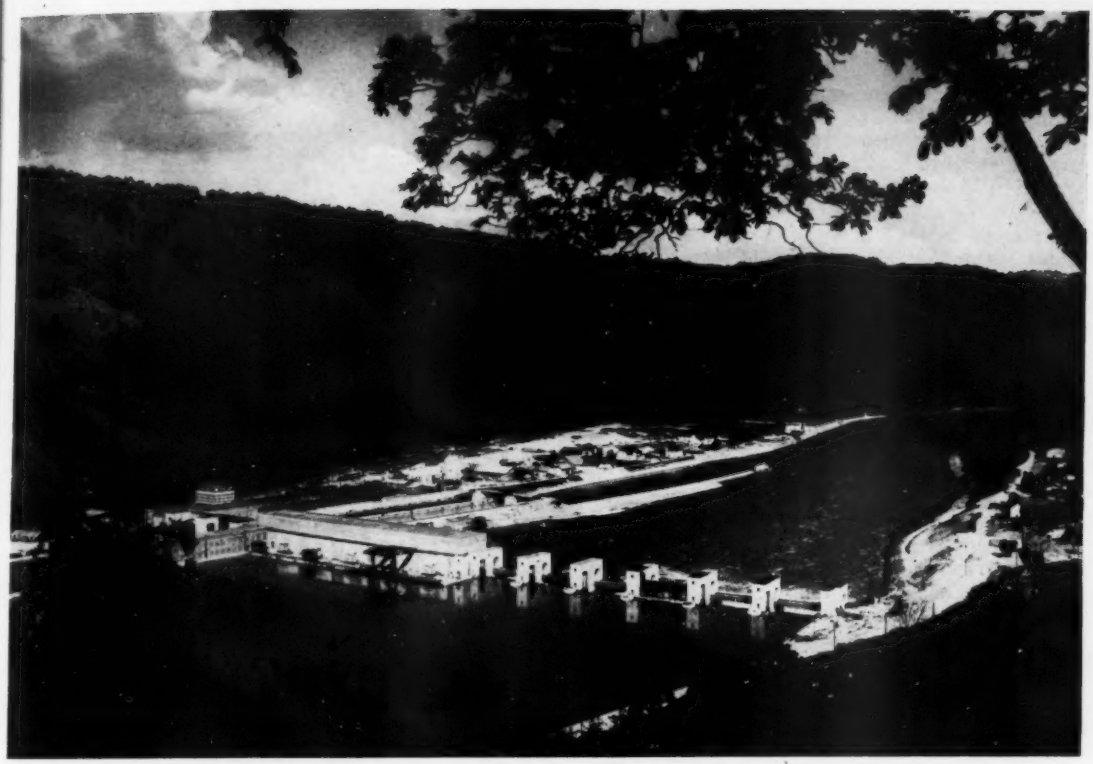


Fig. 1. General view of Jochenstein power station

Jochenstein

This run-of-river plant is a joint enterprise which has been constructed on the Danube by the Austrian and German power authorities

By DR. E. KÖNIGSHOFER

IN the 20 km. long section of the Danube which forms the border between Austria and Germany a large power plant was completed in September, 1956, that is of interest not only because of its size and the technical solutions applied, but also because of the high degree of co-operation that was achieved between the two states and the relatively short time taken to complete the scheme. This rapid completion was achieved in spite of the fact that progress was retarded first by floods of a severity not experienced for a period of over 450 years, and later by a catastrophic ice formation on the Danube by which substantial losses were incurred, involving a considerable amount of extra work. There is every reason, therefore, to supplement the report which was published in this periodical in the July 1954 issue.*

* Page 275.

Fig. 2 shows the situation and location of the site. In the centre of the border section of the Danube is the Jochenstein rock, a landmark of the Danube valley, which, according to the ruling of the competent authorities for the preservation of natural landmarks, must in no way be affected when building the plant. The Inn and Ilz rivers join the Danube near the German city of Passau. About 6 km. upstream of the confluence the Kachlet power plant is situated and this plant limits the backwater space allowable.

Historical Background

Long before the hydro-electric installations were thought of the inhabitants of the land adjoining the Danube were concerned with improving this waterway for transport purposes. There is evidence that even in prehistoric times it was used for navigation

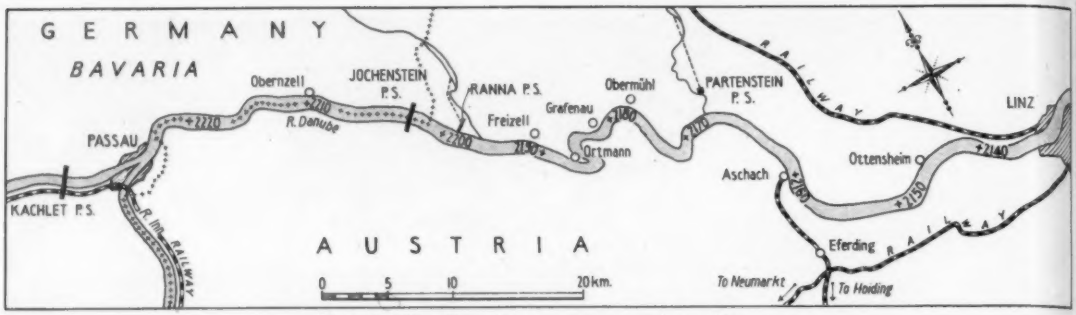


Fig. 2. The Danube downstream from Passau

purposes, and Charlemagne, at the turn of the eighth century, envisaged the construction of a canal connecting the Rhine and the Danube. It was not until about 100 years ago, however, that the regulation of the Danube was first initiated in Bavaria and later in Austria. Towards the end of the 19th century construction work on the Rhine-Main-Danube canal was commenced.

The length of the Austrian Danube, including the Austro-German border section, is about 350 km. and the available head about 150 m.; the utilisable water flow may be assessed at an average of 2,000 cu. m. per sec. Consequently a total installed capacity of 2 million kW and a production of 14 billion kWh per annum could be envisaged.

The engineers who have been planning this power development have always had to keep in mind the navigational requirements, and this was done when the Kachlet power plant, upstream of Passau, was constructed (1922 and 1928). During this period, Oskar Vas, the well-known Austrian expert for hydro-electric installations, suggested the establishment of a committee for setting up an overall development plan for the Danube. The plan elaborated by this committee provides for a progressive development in fourteen stages. The first stage is concerned with the stretch of river below Passau, in the neighbourhood of Jochenstein. Subsequently this scheme was enlarged and modified by a number of Austrian, German and Swiss experts who were concerned with developing the Danube from Passau to Linz. Their plans, however, were not realised, not even after the annexation of Austria by Germany when the Alpen-Elektrowerke A.G. was entrusted with the exploitation of Austria's hydro-power resources. This company did, however, initiate the construction of the Ybbs-Persenbeug stage (cf. WATER POWER, June 1956).

When in 1945 the second Austrian Republic came into being the task of developing Austria's hydro-power resources was conferred upon the Verbundgesellschaft which suggested the conclusion of an agreement concerning Jochenstein between the governments of Austria, Western Germany and the Free State of Bavaria. An Austro-German company was set up in 1949 and proceeded to elaborate plans which led to the establishment of the joint Austro-German Donaukraftwerk Jochenstein A.G. (Jochenstein Power Plant Company) in 1952. At that time Austria was occupied by foreign troops so that a joint-stock company could not be set up by way of a State Treaty but only by way of an inter-governmental agreement whereby, *inter alia*, provision was made for the following:

(1) Construction costs in respect of the power plant

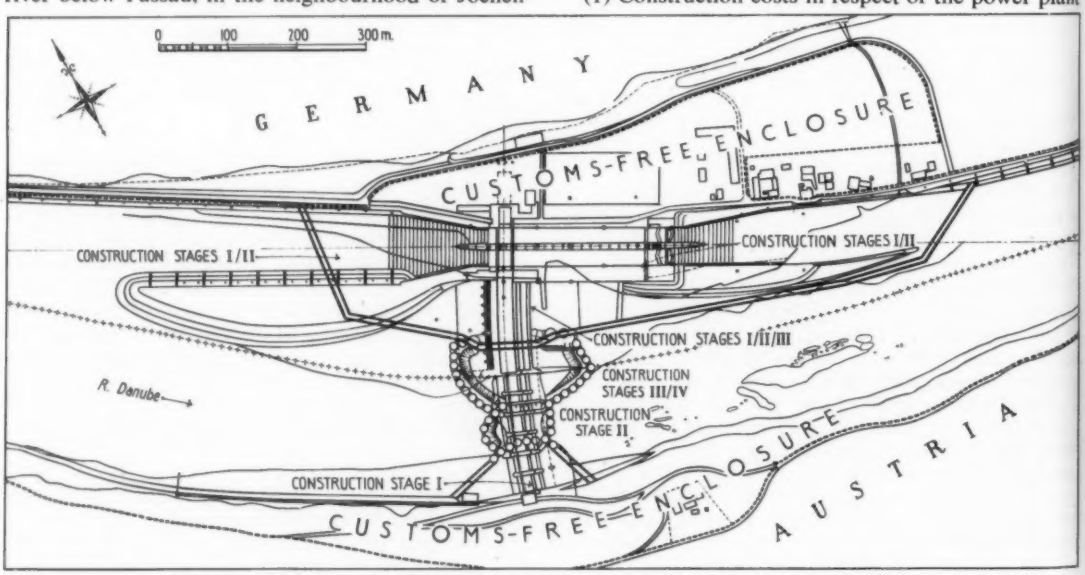


Fig. 3. Layout of cofferdams in relation to the four construction stages

to be equally shared between the two contracting parties.

(2) Both countries to be given equal consideration in placing orders for machinery, building materials, etc.

(3) Both countries to share in the employment of labour for the building work and operational tasks.

(4) As the backwater extends beyond the border section into German territory, Austria has undertaken to assure an additional production of energy by artificially deepening the tail-water channel.

(5) Both parties have provided for the customs-free delivery of the goods supplied by them for the construction of the plant. This provision was complied with by establishing an enclosed customs-free area.

The provision under (2) does not mean that supplies and services are partitioned according to the areas in which the orders are placed but rather that each individual commodity used, such as cement for example, has to be supplied half by Germany and half by Austria. Such a provision, of course, cannot be literally applied as the prices of materials and the costs of services may differ considerably, and in point of fact the orders are placed in accordance with the prices ruling. A rate of evaluation was fixed by which proportional amounts of material are supplied and a proportional number of working hours allocated to each country. As the Donaukraftwerk Jochenstein A.G. has its headquarters in Passau, German legal provisions are applicable and the balance sheet is made up in DM.

Contracts for the main constructional work were awarded to a co-operative concern comprising four Austrian and three German firms.

The agreement outlined here soon began to show defects, and questions arose for which no provision had been made. The two contracting parties managed, however, by exercising mutual understanding and through their co-operative efforts, to find an acceptable solution for all problems so that the construction of the plant went forward without any undue friction or differences of opinion.

Fig. 4. Sheet piling and cofferdams for Construction Stage I

Fig. 5. Looking towards right bank during Construction Stage II

The Project

The flow of the Danube, which has a catchment area of 40,000 sq. km., is entirely different from that of the Inn, which has a catchment area of 26,000 sq. km. The Danube has more the character of a lower Alpine or even a lowland river, and thus has its main water flow in autumn and spring, whereas the Inn is essentially fed from glaciers and has its maximum flow in summer. These circumstances result in a comparatively balanced flow for the Jochenstein power station.

The river-bed load and suspended matter transported in the Jochenstein section are influenced by two power plants situated on the Danube and the Inn upstream of Passau. The storage basin of the Kachlet plant collects virtually all the gravel, so that very little bed load is transported from the upper Danube. On the other hand, the Inn, in spite of the Braunau power plant, deposits large quantities of sediment at Passau. It is intended to remove this by means of dredging operations and to deposit it again in the river bed below Jochenstein.

The site at which the plant has been erected consists mainly of solid rock. The principal construction comprises two locks, one for the boats going upstream and the other for the boats going downstream, each having a free width of 24 m.

Various matters had to be considered when choosing the maximum water level in view of the upper limit imposed by the Kachlet plant. Further, the undisturbed discharge of the sewage from Passau had to be assured and the cost of protecting the villages on the Danube against floods had to be taken into account.

After a thorough investigation a maximum water level of 290 m. above sea level was decided upon, this forming the most favourable balance between development costs and maximum power production. In order to observe this agreed maximum, the water level will have to be lowered quickly, and measures towards this end are taken as soon as the medium level is exceeded.

The question as to the river bank on which the generating station should be located was easily answered, as the flood flows stream off on the concave right bank, leaving the left bank the obvious choice for the generating station and locks. In order to improve the water flow, the generating station and the weir have been planned in a slight curve—an arrangement which also enabled the architectural design to be improved. The radius of curvature of the power plant is 1,500 m.

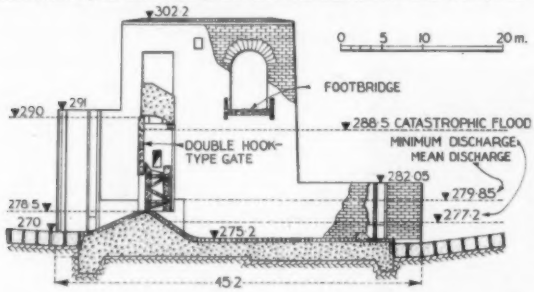


Fig. 6. Section through spillway structure

Constructional Details

The weir has six openings with a free width of 24 m. each. It is closed on the one side by the pillar which separates it from the power house, and on the other side by the shore pillar and the string walls which afford protection to the Austrian (right) bank of the river. The weir has a total length of 174 m. and its hydraulic form and dimensions were ascertained by means of models. Fig. 6 shows a sectional view of a typical pillar. Drainage pipes have been inserted in the foundations for relieving the upward hydraulic pressure.

The weir is closed by means of hooked twin sluices, which in their maximum position have their lower edges one metre above the floodwater level. When all the turbines are shut down (as in the case of a transmission breakdown) the sluices are lowered and the entire flow is discharged over the weirs.

The stoplogs, both upstream and downstream, are operated by a 100 ton floating crane, which also handles the stoplogs for the lock and the generating station.

The power house has been designed for a water flow of 1,750 cu. m. per sec., which, in a normal year,

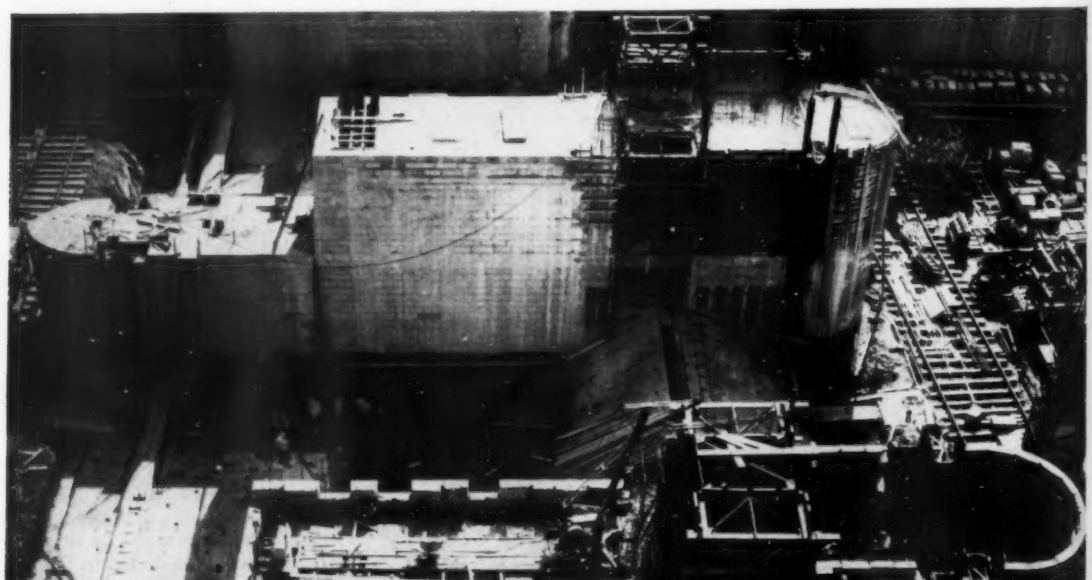


Fig. 7. Spillway section under construction, September 1953

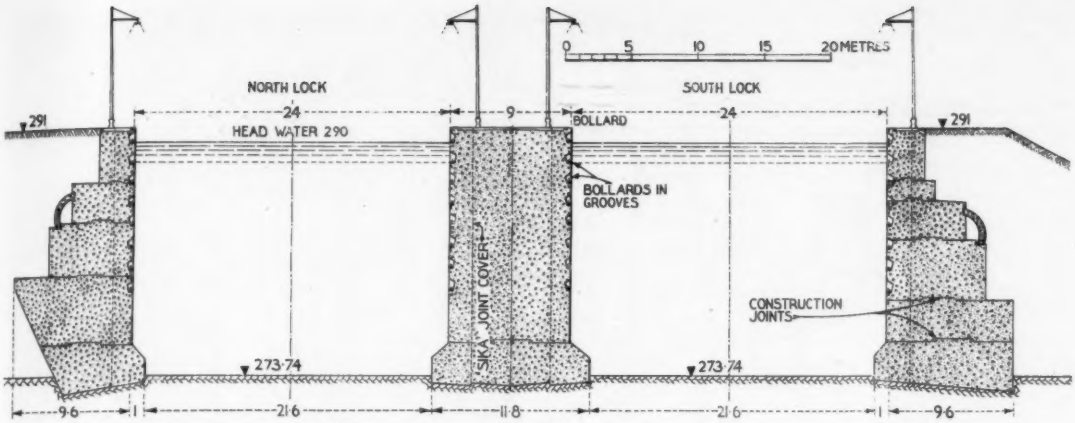


Fig. 8. Cross section through lock structure

is only exceeded in a period of 100 days. As a result of comparative studies it was decided to distribute the utilisable water flow to five turbines installed in a single generating station, unlike the Ybbs-Persenbeug power house, which is divided into two equal parts. The idea of installing an even number of generating units was abandoned as the Danube valley is too narrow for six units and four units would have required deep and costly excavation work. The installation of the five turbines and the separating pillar determined the length of the power house, which is 160 m.

The generating plant consists of five Kaplan units each capable of passing 350 cu. m. per sec. at a gross head of 9·60 m. Each is 7·4 m. in diameter and develops 39,400 h.p. The direct-coupled three phase synchronous generators are of 35,000 kVA capacity each and operate at 9 kV. Mounted on the trashrack platform are five 35,000 kVA 9/220 kV transformers.

Fig. 9. Floating crane "Jochenstein" and attendant craft in the lock

In the power house two cranes, each of 75 tons carrying capacity, which can be coupled together, have been installed. The crane runway extends over the two lock bridges up to the northern access road.

Fig. 10 gives a cross section of the power house. The emergency sluices are operated by a gantry crane. To prevent the formation of cracks in the 71·7 m. wide power house the section was subdivided into three parts, so enabling the central portion or turbine hall to be shortened by 31·3 m.

Fig. 8 gives a cross section of the lock and shows how the lock chambers have been erected in the form of stairs, the central walls being 9 m. thick. Additional data in respect of the locks are: usable length 230 m.; head bay 500 m. long and 100 m. wide; tail bay 85 m. wide. The lock gates have been so designed that they may be used for carrying off floods. At their upper gates sluice-like shutters have been installed and the lower gates are designed as rolling vertical-lift sluices. An electric interlock prevents the sluices of the upper gates from being operated when the lower rolling vertical-lift sluices are not closed and *vice versa.*

A double bridge has been constructed across the lock and serves to connect the power house with the northern embankment of the river, to form a runway for the power-house crane, to accommodate the power and control cables and to act as footbridge for the staff and the public.

The two bridges are of the box type, the concentrically acting crane loads being taken up by a torsion-resisting construction so that the box section is used as a carrying system. The cable ducts laid in the interior of the bridge are cooled by blowers. For the service way to the station the upstream bridge is used, while the downstream bridge is essentially for public traffic. The bridges are supported by the weir pillars, the roadway being placed between the main beams, which thus serve as protective railings. They have been designed to accommodate six-ton motor vehicles.

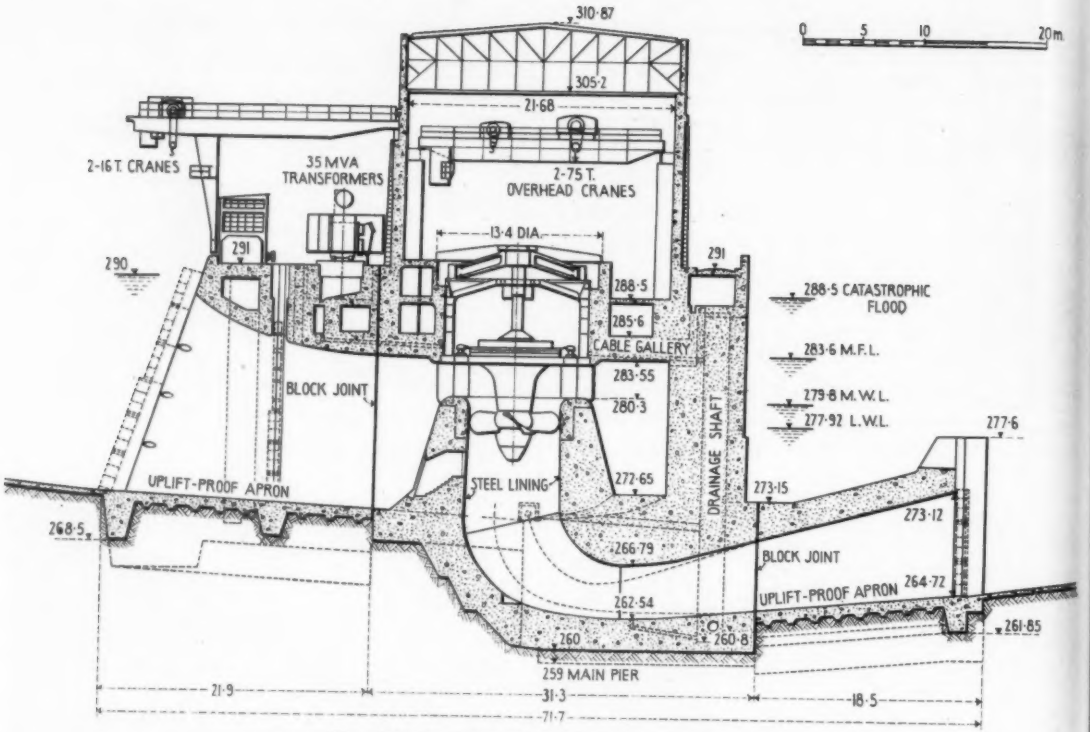


Fig. 10. Cross section through power house

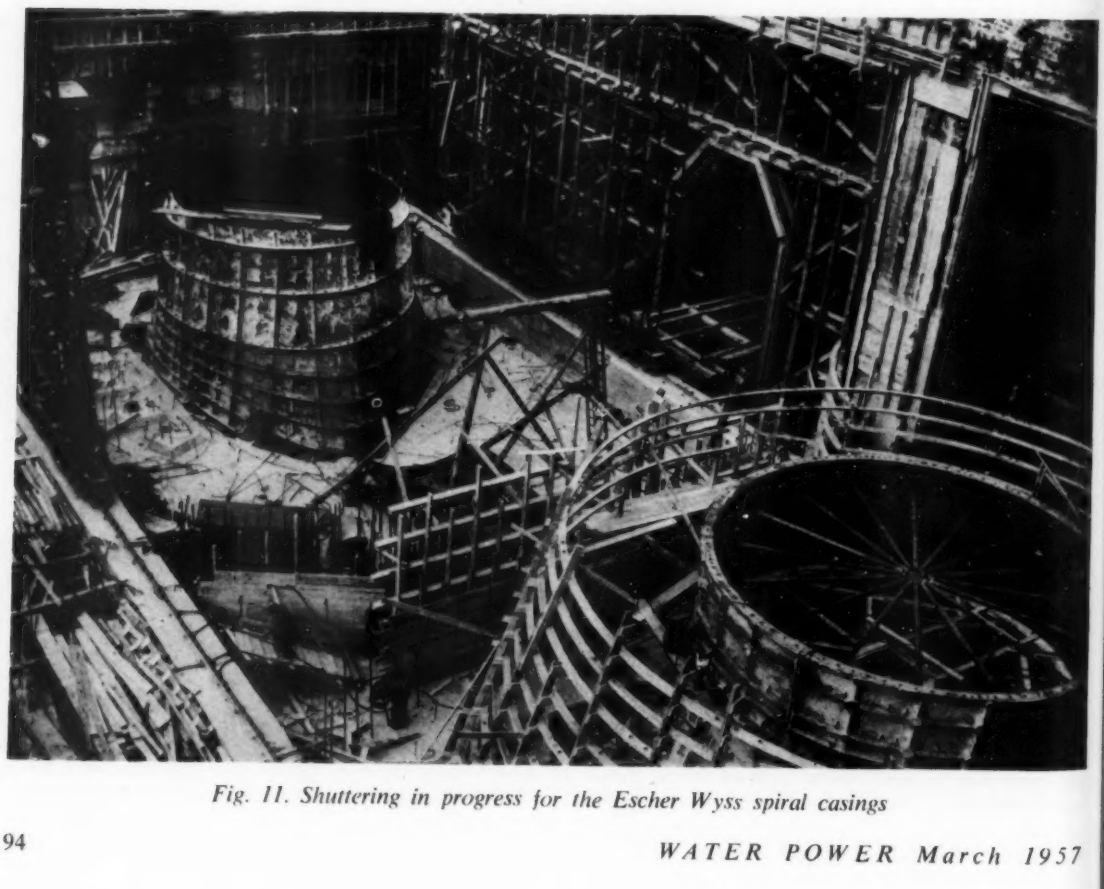


Fig. 11. Shuttering in progress for the Escher Wyss spiral casings

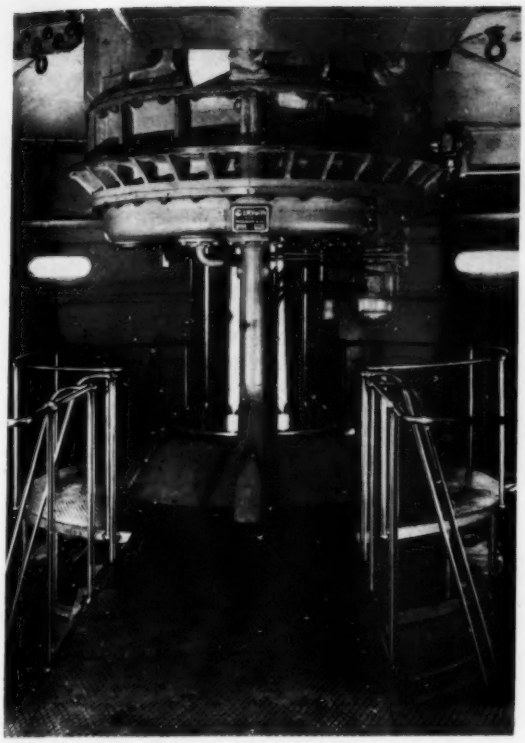


Fig. 12. Shaft chamber of one of the Voith turbines

Some 500,000 cu. m. of concrete was required, four-fifths of this being of the mass variety and one-fifth steel reinforced. Gravel taken from the excavations was used, and for the washed and separated aggregates intermediary deposits were opened up. As binding agent trass cement was used. Ten storage silos were provided having a total capacity of 4,000 tons. The concrete-mixing plant was supplied by C. S. Johnson & Company and had a mixing capacity of 2,800 cu. m. per 20-hour day. In addition a small auxiliary mixing plant was erected. All the weighing equipment was hand operated.

Backwater Basin

The backwater basin, about 30 km. long, required extensive protective works along the river banks, particularly in the neighbourhood of villages and townships. Also the water-supply system of the city of Passau had to be reconstructed; the village of Obernzell had to be surrounded by a protective wall to a total length of 1,163 m. As a protection against damage caused by floods, wave action and drift ice, the banks had to be revetted, also riparian rights had to be preserved by embankments, roads to be constructed or rerouted, and certain streams had to be diverted. Drainage work had also to be undertaken and pumping stations erected for dealing with the ground and waste waters. A new approach road between Obernzell and Jochenstein was necessary and buildings endangered by the backwater had to be evacuated and the owners indemnified. Cellars threatened by the raised ground-water level had to be protected, new bridges had to be built and a new ferryboat landing pier constructed. On the southern embankment alone 1·3 million cu. m. of earth were removed, over 200,000 cu. m. of stones were placed, about 14,000 cu. m. of concrete were poured and about 65,000 sq. m. of road surface newly constructed. On the German (northern) bank about 785,000 cu. m. of earth were removed, about 25,000 cu. m. of concrete poured and some 180,000 cu. m. of stones dug in.

Finally the whole backwater area was planted with trees and shrubs to take the rawness off the new constructional work and to create a harmonious whole with the general character of the landscape.

Deepening of Tailwater Level

To increase the working head of the power plant the tailwater level was lowered by 1·20 m., over a distance of about 7 km., by dredging and blasting. Part of the material so removed has been deposited on the banks of the Danube, below the deepened section, in order to return it to the river in case the bed is further lowered, by natural erosion, to an extent that would not be acceptable to the navigational interests.

Building and Assembling Programme

For the development of the power plant (Fig. 3) a definite programme was worked out and provided for the following: (1) construction work was to be commenced on November 1, 1952; (2) construction was to be completed by September 30, 1956; (3) navigation must not be impeded noticeably by building operations; (4) to reduce interest charges, partial operation should be started as early as feasible.

In order to assure the execution of work according to plan, four construction pits were excavated. This was done successively so that navigation should not

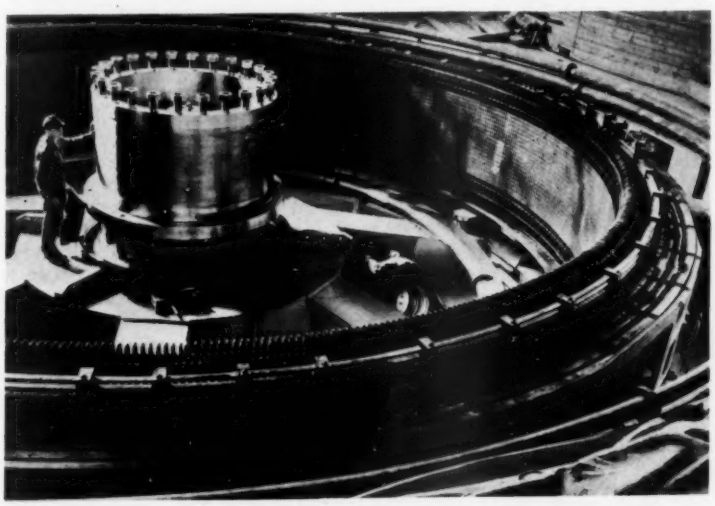


Fig. 13. Siemens-Schuckertwerke generator in course of erection

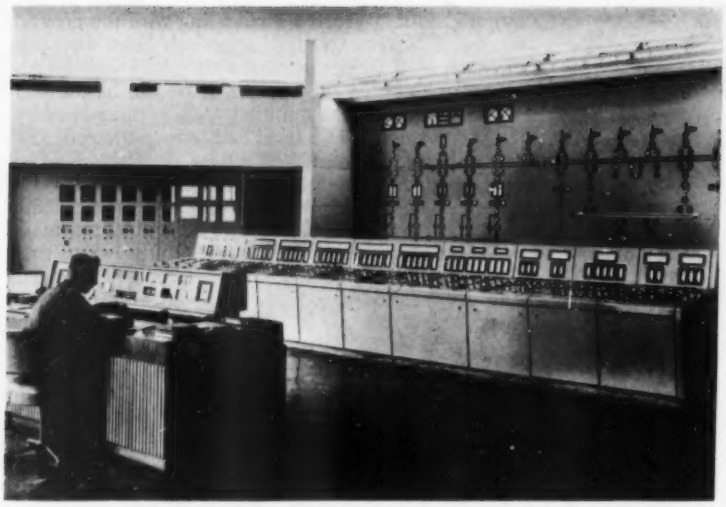


Fig. 14. The control room at Jochenstein

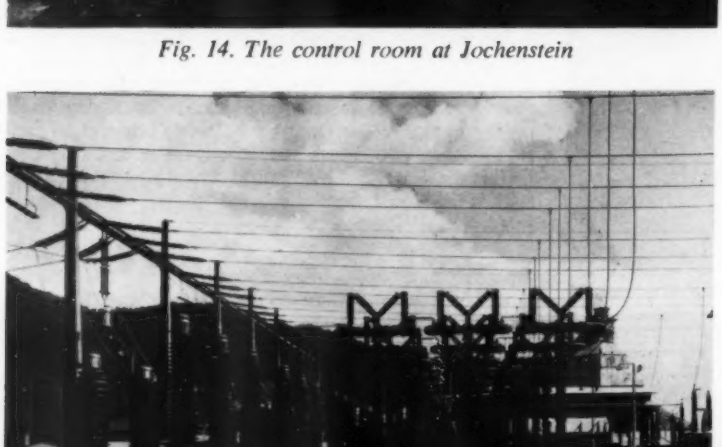


Fig. 15. View of the 220 kV switchyard

be interrupted. Four construction periods were envisaged, but before dealing with them a short description of the four construction pits will be given with the aid of Fig. 3 (for further details see also the account given later of the flood disaster of 1954).

The first, designated "Construction Pit I North," was excavated on the northern bank. It was about 1 km. long and included the whole area reserved for the entire lock and three generating units. In the second, called "Construction Pit I South," the two southern weir openings were erected. Some 80 m. south of No. I North Pit was the northern border of the isle-shaped "Construction Pit II" in which two further weir openings were erected. The 80 m. wide channel served for navigation purposes and was kept open until the southern lock had been completed. It was not until ships could pass through the lock that the final pit No. III was excavated; in this the rest of the weir openings and the foundations of the remaining generating units were erected.

The construction programme was divided up into three building periods. In the first of these the locks, head bays and power house (generating units 1 to 3) were partly completed together with the work to be done in the right part of Pit I in respect of the 1 and 2 weir openings.

In the second period the constructional work was continued in the left part of Pit I and the weir openings 3 and 4 were begun in Pit II.

In the third period the work in the left part of Pit I was completed, *i.e.* the first three generating units were erected, and the work in Pit III continued on the final two generators and weir openings 5 and 6.

In the fourth period the work in Pit III was completed.

Actually navigation through the southern lock began on October 1, 1954, partial storage started on April 1, 1955, and the first three generating units put into operation on July 1, 1955. Full storage operations started on January 1, 1956, and on September 30, 1956, the remaining two generating units were put into operation.

Power-House Equipment

The turbines are five-bladed Kaplan machines and have been designed for a total water flow of 1,750 cu. m. per sec., *i.e.* 350 cu. m. per sec. each. Each wheel is 7·4 m. in diameter, operates under a rated head of 9·6 m., and is coupled to a 29,000 kW alternator. The average total flow on a yearly basis amounts to 1,450 cu. m. per sec. Optimum turbine efficiency is achieved with a flow of 200 cu. m. per sec. in each turbine, when all five turbines are in operation at the same time. The five 9,000 V generating units have a nominal output of 35,000 kVA each, the power factor being 0·8.

Each generator is directly connected to one of a bank of transformers, all the units of which have an unusually large range of regulation (180–280 kV). The open-air switchyard is screened from the view of passengers on the river boats by a clump of trees.

Energy Data

Making due allowance for the energy required to service the plant and taking into consideration the storage capacity created by the weir, Jochenstein will produce 920 million kWh per annum, 46% of which will be available in winter and 54% in summer. This will result in a saving of 400,000 tons of coal per annum, *i.e.* 200,000 tons for each of the two contracting parties. In a normal year 88% of the river flow

will be used for energy production, excess flow and loss in the locks accounting for the remaining 12%.

Power Transmission

Half of the electric energy produced at Jochenstein accrues to the Österreichische Verbundgesellschaft and/or to the Bayernwerk A.G., Munich, as contractual partner of the Rhein-Main-Donau A.G., Munich. The 220 kV overhead transmission line from the generating station to the St. Peter transformer station, on the Austro-Bavarian border, was also a joint undertaking, the cost being shared by both parties. Division of the energy produced is effected by keeping account of the deliveries made. The transmission line from Jochenstein to St. Peter runs partly through Bavarian and partly through Austrian territory, and like the operation of the power plant itself is the responsibility of the Österreichische Verbundgesellschaft, whose central office is in Vienna.

Fig. 16. The workings during the July 1954 flood

The Flood Disaster of 1954

On July 8, 1954, the water flow of the Danube amounted to 2,600 cu. m. per sec., increasing to 3,500 cu. m. per sec. towards midnight. On the 9th it rose gradually to reach a maximum of 9,600 cu. m. per sec. on July 10. Subsequently the water level fell slowly, but on the 20th still amounted to 3,500 cu. m. per sec. At this critical time the lock installation was virtually completed, and preparations were being made in Pit I for mounting the generating units; in Pit II erection of the weir pillars was almost finished.

The coffering around Pit I could resist a water flow of up to 6,000 cu. m. per sec. This pit had an area of 143,000 sq. m., being enclosed by 513 m. of ordinary sheet piling and an earth dam, 180 m. of coffering having a height of 14 m. with sheet piling every 10 m., and 571 m. of cofferdam constructed in concrete. In the concrete portion there were nine openings having a free width of 2·5 m., a height of 1·9 m., and provided with gates. Pit II was enclosed by a concrete cofferdam 290 m. in length, and by 7 + 5 circular cells having a diameter of 12¾ m. and a height of 62·5 m. The enclosure was designed for a water flow of 5,500 cu. m. per sec. Pits I and II had to be evacuated in the forenoon of July 8 and at 9.30 p.m. Pit II began to fill with water, a process that was completed within 2½ hours. As the generating area of Pit I was separated from the lock area it proved necessary to open up further flood outlets in the concrete cofferdam by blasting. This was done at 11.30 p.m. and within 2½ hours the pit of the generating station was flooded. At 5 o'clock on July 9 more of the concrete cofferdam had to be blasted away and at 7 a.m. the lock pit had been completely filled. Jochenstein village had to be evacuated and the foundations of the switchyard were inundated.

It was not until July 12 that preparations could be started for restoring the pits. The structures were not found to be damaged by the flood but a considerable loss of building material and constructional equipment had to be made good. The last flood of such dimensions occurred no less than 450 years ago.

This unfortunate incident shows how important it is to consider, as far as is economically warrantable, the possibility of such an unusual flood, especially in planning run-of-river plants. At Jochenstein the planning was done on the basis of a flood characteristic which is not likely to occur more than once in a period of 100 years, but obviously this period does not give immunity from a flood of almost unprecedented severity. Such an excessive flow can only be mathematically computed on the basis of the probability calculus.

Ice Jam of 1956

During the last few days of January 1956 a cold wave set in which gradually gained momentum. First, marginal ice began to form and later spread over the Danube but could be removed quite effectively by the available ice breakers. A further drop in temperature brought down drift ice and soon afterwards a coating of floating ice was formed which gradually grew upstream until it reached the alarming length of 25 km. Not only had this ice to be cleared to ensure navigation but also to prevent an excessive rise in the water level caused by the blocking of the flow. Provision had also to be made lest the ice masses should be set free by a sudden thaw and damage both the works and the river banks. The thaw did not set in before March 6. Until then an icebreaker and two specially adapted motor ships were used to keep the traffic going. By blasting the ice the overflow levels were kept sufficiently low to prevent serious difficulty. The broken ice was released by opening the weirs. After the thaw set in during the first days of March it was still necessary to conduct loosened masses through the weirs but no damage was caused.

Generally speaking, this experience suggests that in navigable rivers the formation of ice should be permitted to go on undisturbed in the backwater basin for some time, and icebreakers should not be put into service too early. If very much drift ice gets into the backwater basin an ice jam is formed, the ice sheets

being brought into a vertical position and pressed together until the entire surface of the river is covered. On the Danube an ice jam has an average thickness of three to four metres but in an ordinary way the thickness of the ice amounts to some 30 cm. only. An ice jam may cause the water level to be raised substantially and the upper end of the backwater basin may be raised as much as three to four metres on the Danube. The only effective means of fighting the formation in the backwater basin is the icebreaker, as blasting and other methods can at best only yield local and limited results. Icebreakers do not give rise to any particular difficulty. Even a severe jam may be fought successfully, but it should not be overlooked that the broken ice is carried away by the current, so that the breaker should start operations from the weir and proceed upstream. A sufficiently wide water channel should be preserved behind the icebreaker, because if it is too narrow, it may get blocked and the icebreaker be cut off. Under otherwise equal conditions an icebreaker can pierce through an ice cover upstream but not downstream.

Special arrangements should be made to ensure that the broken ice is carried away via the weir in sufficient quantity. This may be achieved either by alternately raising and lowering the water level or by using the icebreaker at specific points.

Staff

Böck, Herbert — Overall supervision of planning and construction.
Fuhse, F. — Preliminary project and building programme.
Hofman, E. — Overall planning.
Krauss, K. — Machinery and electrical equipment.
Mattel, V. — Erection programme.

Fig. 17. The Danube during the February 1956 ice jam, showing MV "Wallner" in use as an icebreaker

Suppliers

J. M. Voith G.m.b.H., Heidenheim — Turbines.
Escher - Wyss G.m.b.H., Ravensburg — Turbines.
VÖEST, Linz — Accessories for Voith turbines, steel constructions.
Maschinenfabrik Andritz AG., Graz — Accessories for Escher-Wyss turbines, and for the lock - operation equipment.
Escher - Wyss G.m.b.H., Zürich — Rotors for Escher-Wyss turbines.
Dortmunder Union Brückenbau A.G., Dortmund — Operating devices for lock gates.
Stahlbau Rheinhausen, Rheinhausen — Lock gates and operating devices.
August Klönne, Dortmund — Lock gates.
Georg Noell & Co., Würzburg — Cranes.
Waagner-Biró, A.G., Wien und Graz — Steel constructions.
Simmering - Graz - Pauker A.G., Wien — Stoplog crane.
B. Maier K.G., Brackwede — Operating device for rake cleaner.
Theodor Hitzler, Regensburg — Icebreaker.
Schiffswerft Linz A.G., Linz — Icebreaker and other vessels.
Maschinenfabrik Augsburg - Nürnberg A.G., Werk Gustavsburg — Floating crane.
Siemens - Schuckertwerke A.G., Berlin und Erlangen — Generators, exciters, electrical equipment of weir - operating equipment.
Siemens - Schuckertwerke G.m.b.H., Wien — Accessories for generators, switchboards.
Allgemeine Elektricitäts-gesellschaft, Frankfurt — Generators, electrical equipment for lock-operating devices.
AEG-Union, Wien — Accessories for generators, protection devices, 9 kV switchgear.
Elin, A.G., Wien — Generators, transformers switchgear, switchboard.
BBC Mannheim and Wien — 220 kV switchyard busbar protection, voltage regulators.
Elektrobau A.G., Linz — Transformers.
Sprecher & Schuh, Linz — Protection gear.
Siemens & Halske A.G., München, and Siemens & Halske G.m.b.H., Wien — Telephone installation, hydraulic apparatus.
Felten & Guilleaume, Carlswerk A.G., Köln-Mühlheim — Telephone cables.
Kabel- und Metallwerke Neumeyer A.G., Nürnberg; Bayka, Bayer. Kabelwerk Riffelmacher & Engel hardt, Roth b. Nürnberg — Control and metering cables.

Hydro-Electric Progress in Canada 1956

The Water Resources Branch of the Department of Northern Affairs and National Resources has issued its annual review* of current water-power development throughout Canada, and of other construction pertaining to electrical power supply and distribution

IN order to meet the increasing demand for electrical power from commercial and domestic sources, construction of hydro-electric plants in Canada was accelerating during 1956. The appreciable amount of 845,000 h.p. of new capacity was added during the year and construction was very active on other projects comprising over 1,500,000 h.p. to come into operation during 1957 and probably more than 2,500,000 h.p. in 1958. The greatest single addition to capacity in 1956 was that of 450,000 h.p. at the Bersimis No. 1 development of the Quebec Hydro-Electric Commission, the remainder of the increase being distributed among most of the other provinces. There are also several sites of high capacity which are presently under investigation and on which it is probable that development will be undertaken within a few years' time. The total installed capacity of water-power plants in Canada is now listed at 18,356,148 h.p. which, however, represents less than 28 per cent. of total resources.

A review of the year's activities in central-station construction and in distribution facilities is given below by provinces.

British Columbia

Hydro-electric construction was very active in British Columbia with 243,500 h.p. of new capacity installed during the year, about 500,000 h.p. under construction for 1957 operation, and a considerable amount in the planning or early development stages for later service.

The British Columbia Power Commission installed at its Ladore Falls development on the Campbell River, the first of two units, each consisting of a 35,000 h.p. Francis-type turbine under a 122 ft. head driving a 30,000 kVA generator; the second unit is expected to be in service in the spring of 1957 and provision will be made for the addition of a third unit. The plant is of the outdoor type and will be remotely controlled from the John Hart station farther downstream. About two miles below the outlet of Upper Campbell Lake, the Commission is proceeding with its 140 ft. head development with initial installation of one 42,000 h.p. unit scheduled for completion by December, 1957, and with provision for two similar units at a later date. A 35,000 h.p. development with a net head of 735 feet, located on the Ash River near Alberni, is in prospect for completion in the winter of 1958-59. On the mainland, the installation of a third unit at the Whatshan development near Needles, comprising a 16,500 h.p. reaction-type turbine and an 11,250 kW generator, should be completed by January, 1957.

Transmission lines scheduled for completion by the end of March, 1957, include a total of 73 miles of 138 kV line from Ladore Falls to the John Hart station, and from Whatshan plant to Vernon; a total of 135 miles of 60 kV line from Kamloops to Merritt, Nakusp to New Denver, Kamloops to Savona and Canal Flats to Ta Ta Creek. Thirty miles of line between Athalmer and Canal Flats will be reinsulated from 33 kV to 60 kV. Scheduled for completion by the end of March, 1958, are ten miles of 138 kV line between the Ladore plant and the Upper Campbell development. The 138 kV Dunsmuir and Vernon switching stations are scheduled for completion by March, 1957, and the 138 kV Whatshan and Prevost switching stations by March, 1958. Transformer stations at Merritt, Savona and New Denver are scheduled for completion by March, 1957, and at Prevost, Alberni, Crofton, Duncan Bay, Duncan and North Kamloops by March, 1958.

The British Columbia Electric Co. Ltd. is proceeding with the development of its Bridge River power-plant system. The Seton Creek plant near Lillooet was completed with the installation of one 58,500 h.p. turbine under a 147 ft. head driving a 42,000 kVA generator. At the La Joie dam, construction is under way with one 30,000 h.p. unit scheduled for completion in the fall of 1957. Work has commenced on the Bridge River No. 2 development involving a storage dam on the Bridge River, a second tunnel through Mission Mountain and a new power house on Seton Lake about one-half mile upstream from the present plant. Four units of 80,000 h.p. each will be installed, the first three scheduled for 1959 and the fourth for 1960; generators will be rated at 65,500 kVA each.

Water for the La Joie reservoir will generate power at three different sites within the Bridge River System; first, at the La Joie plant, then at the Bridge River No. 1 or No. 2 plants and finally at the Seton Creek plant. Work is continuing on the Cheakamus development of 190,000 h.p. in two units, scheduled for service in the fall of 1957 and involving the diversion of water from the Cheakamus River near Garibaldi to the Squamish River by means of a dam at the outlet of Daisy Lake and an 18 ft. diameter tunnel 6¾ miles in length. At the 4,000 h.p. development at Clowhom Falls, purchased from the British Columbia Power Commission in May, 1956, together with the Commission's Sechelt peninsula system, work is under way on the replacement of the present plant by a single unit comprising a 40,000 h.p. turbine and 31,500 kVA generator sheduled for operation in the fall of 1957. A new dam is to be constructed to give a maximum head of 174 ft.

* Bulletin No 2,551, "Hydro-Electric Progress in Canada, 1956." Copies of this bulletin may be obtained free of charge upon application to the Director, Water Resources Branch, Department of Northern Affairs and National Resources, Ottawa.

A 132 kV submarine cable interconnection between Vancouver Island and the mainland, consisting of 25 miles of overhead line and 19·6 miles of submarine cable, was completed during the year, making available an additional 120,000 kVA for use on the Company's Vancouver Island network. The new Arnott substation, comprising two 66,000 kVA, 230/132 kV transformers, is the mainland terminal which is tied into the existing 132 kV lines at the new Stratford substation on Vancouver Island. Work is proceeding on the second transmission line between Bridge River and Vancouver, and when the Bridge River-Creekside portion is completed in 1957 the new line will go into operation at 345 kV. At its southern terminal the line connects with the existing Wahleach-Vancouver line, and on completion will provide a 345 kV circuit from Bridge River to the new Ingledow receiving and switching station at Surrey, which is equipped with 345/230 kV and 230/60 kV transformers. Forming a part of the 97 mile, 132 kV line completed during the year to supply the Powell River and Sechelt areas, is the 10,100 ft. crossing over Jervis Inlet which is one of the longest overhead crossings in existence. The Cheekye substation near Squamish was constructed with two 66,000 kVA transformers to provide the 132 kV supply for this line. In addition, substations in North Vancouver, in the University area and in Victoria were completed as well as numerous additions to existing substations.

The Aluminum Company of Canada Limited installed the fourth 150,000 h.p. unit in its Kemano plant and construction work for the fifth 150,000 h.p. unit is under way with operation scheduled for about mid-1957. The completion of the fifth unit will bring the total installed capacity of the plant to 750,000 h.p. In active prospect for Kemano is another 150,000 h.p. unit for operation late in 1958.

The City of Nelson is adding 2,000 kVA capacity to its Fairview substation together with an additional feeder section; also 1,500 kVA to City substation No. 2 with an installation of 4,000 V switchgear. Distribution voltage is being changed from 2,300 to 4,000 V.

The East Kootenay Power Company Limited is completing 13·6 miles of 66 kV transmission line to connect with the British Columbia Power Commission line near Ta Ta Creek.

The West Kootenay Power and Light Company Limited in conjunction with the British Columbia Power Commission is commencing the construction of a transmision line between their South Slocan plant and the Whatshan plant of the Commission to provide power from the Kootenay River plants to meet the growing demand of the north and south Okanagan areas. The line is expected to be in operation by the fall of 1957.

The Crown Zellerbach Canada Limited constructed a 6,900 V transmission line 1¾ miles long to serve the west end of the Ocean Falls townsite and the Martin Valley subdivision.

The Powell River Company Limited completed in March its project which diverted water from the upper Theodosia River into Powell Lake and increased the firm power output of its hydro-electric plant by about 2,000 kW.

Northwest Power Industries Limited continued with surveys on the Nass River during the year, concentrating chiefly at the main dam site about 10 miles above Aiyansh and at the control dam site on the Bell-Irving River to provide storage on the Bowser Lake watershed. Included were detailed surveys at the dam sites, aerial mapping of the Nass River, geological surveys and subsurface exploration with diamond drills. In addition, extensive surveys were made around Alice Arm to locate possible industrial sites accessible by sea. The programme will be continued throughout 1957 with a view to reaching the design stage by the fall of 1957.

Yukon Territory

The Northern Canada Power Commission started work in October on its development at Whitehorse Rapids on the Yukon River, about 1½ miles upstream from Whitehorse. The initial installation, scheduled for completion in October, 1958, will consist of two 7,500 h.p. Kaplan units under a 63 ft. head with provision made for a third unit. About three miles of 34·5 kV transmission line will be associated with the development which is intended to supply the Department of National Defence establishment and the privately owned utility company presently distributing power within the municipality.

Northwest Power Industries Limited continued surveys on the proposed Yukon-Atlin-Taku project with extensive diamond drilling being carried out at the Miles Canyon dam site on the Yukon River, on the tunnel locations between Atlin Lake and the site of power plant No. 1 on the Nakinake River as well as at the power house site itself. Surveys are nearly completed for the design of an initial 880,000 h.p. development at power house No. 1 and the Company envisages an ultimate overall development of nearly 5,000,000 h.p.

Alberta

Calgary Power Ltd. is proceeding with the extension of its Cascades power plant by the addition of a second 23,000 h.p. unit, scheduled for completion in October, 1957, to be used mainly for peak-load purposes. The extension will involve an addition to the power house, modification of the intake structure and the installation of a 9 ft. pipeline and an 8 ft. penstock to supply the new unit. The Company is continuing its investigations with respect to proposed extensions to the Spray and Rundle plants which would double the present total capacity of 85,000 h.p. for these two plants. Preliminary investigations are being made into possible hydro-electric developments on the North Saskatchewan River above Rocky Mountain House and on the Brazeau River, a tributary of the North Saskatchewan River.

Transmission network was increased by 96 circuit miles of 132 kV line, 27 circuit miles of 66 kV line and 289 circuit miles of 22 kV line. Two substations were constructed at Wabamun and one each at Gulf Oil and Gainford.

Northland Utilities Limited completed the installation of a Kaplan turbine of 1,000 h.p. in its Astoria River plant near Jasper bringing to 1,800 h.p. the total name-plate rating of the two units. A new 24 in. steel penstock, 1,500 ft. long, serves both units and replaces the wood-stave penstock formerly used.

Saskatchewan

The Saskatchewan Power Corporation, whose transmission network covers a large part of the

southern portion of the province, at present depends exclusively on thermal engines for power production.

The Churchill River Power Company is actively considering the extension of the Island Falls hydro-electric plant on the Churchill River by the addition of a 19,000 h.p. turbine to act as a standby unit. The project is now in the design stage.

Manitoba

The Manitoba Hydro-Electric Board is planning to construct a $30,000,000 hydro-electric development on the Nelson River at Grand Rapid to supply power for a proposed mining development by the International Nickel Company at Moak and Mystery Lakes located about fifty miles west of the power site. Tentative plans indicate an installation of four or five 37,500 h.p. units under a head of almost 50 ft. with provision for three additional units. Engineering studies are proceeding and an early start on preliminary construction is contemplated. The $100,000,000 estimated cost of the mining development would represent the largest single investment in the Province to date. Further investigation at Grand Rapids on the Saskatchewan River has been tentatively discontinued in favour of the Nelson River development. A new approach bridge was constructed at the Seven Sisters power plant on the Winnipeg River and repairs to spillways and two sluice gates were completed at the Great Falls Station.

Interconnection of the southern Manitoba and north-western Ontario electrical distribution systems was effected in October, 1956, to permit the transfer of power between the two systems as required. A 66 kV transmission line between Transcona and Winnipeg was completed during the year.

The City of Winnipeg is continuing with the renovation of its Pointe du Bois hydro-electric station on the Winnipeg River. One new substation and four miles of 60 kV transmission line were to be completed by the end of the year.

Sherritt-Gordon Mines Limited is presently constructing its No. 2 development on the Laurie River with one 7,000 h.p. unit under a net head of 55 ft., which will increase to 14,000 h.p. the total installed capacity on that river. About 20 per cent. of the associated dam structure was expected to be completed at the end of the year; the development will be completed about October, 1957.

The Manitoba Power Commission, which distributes electrical power throughout the province, except for the City of Winnipeg, increased its substation capacity by 11,000 kVA and has completed or has under construction 158 circuit miles of main transmission line and 225 miles of rural distribution line.

Ontario

The Hydro-Electric Power Commission of Ontario completed one moderate-sized hydro-electric installation during 1956 and was vigorously engaged on several major projects; other large additions to generating capacity were in the planning stage.

St. Lawrence Power Project

As the responsible agency for all construction work on the Canadian side of the river for this international project, the Commission pressed forward on a variety of activities involved in the complex undertaking, a work force of 4,500 men being employed at the height of 1956 operations.

Placing of concrete for the main dam and power-house structure was begun in February and, by mid-summer, pours in excess of 2,000 cu. yds. per day were being made. At the year's end, all foundations were completed and draft-tube concrete was placed for the first six units. The Commission's part of the power house will contain 16 generating units with a total turbine capacity of 1,200,000 h.p. with initial service scheduled for 1958 and completion by 1960.

Progress on the main Cornwall dyke was delayed by unfavourable weather during the spring, and again in the early fall. However, work for the diversion of the Cornwall navigation canal, and for the concrete closure-structure at the point where the diversion canal will pass through the dyke, were both ahead of schedule at the end of the year, The diversion canal will be required for service at the beginning of the navigation season in 1957. Under present plans, closure to establish the headpond will be effected in 1958.

Sir Adam Beck-Niagara Generating Station No. 2

The addition of the final four units in the main plant was actively under way. Excavation for the power-house extension and for the penstock slots, and the placing of concrete for the draft-tube floors were completed, and concrete was being poured for the draft-tube piers. Cliff facing was nearing completion and the erection of the penstocks was begun. One unit is scheduled for service late in 1957 and the remaining three in 1958. Each turbine is rated at 105,000 h.p. and total installed capacity of the No. 2 plant will be 1,680,000 h.p.

At the pumped-storage generating station, which is associated with the No. 2 Station and is located one-half mile upstream on the power canal, six reversible pump-turbines are being installed. Water is to be pumped from the power canal into a 700 acre reservoir with a usable water capacity of 16,000 acre ft. The reservoir dyke has been completed and concrete work was finished in the headworks and tailrace areas and in the immediate area of the first two units. When acting as turbines, using water returning from the reservoir to the canal, each unit will have a capacity of 47,000 h.p., under full reservoir head of 85 ft. Unit No. 1 is expected to come into operation early in 1957 and the others each at intervals of about two months. The station is of the semi-outdoor type.

To fulfil the terms of the Niagara Diversion Treaty of 1950 governing the diversion of water for power purposes and to permit the most efficient use, for power, of the water made available by the treaty, work was continued on the control dam structure being built in the Niagara River above the cascades. When completed, the structure will comprise 14 concrete piers and 13 sluiceways each 100 ft. in width and equipped with submersible gates, the whole being spanned by a 1,500 ft. service deck. At the end of the year, nine gates were in operation and concrete work was well advanced on the remaining four sluiceways.

Developments in North-western Region

At the Manitou Falls, on the English River, about 20 miles below Lac Seul, the development which was begun in 1954 was brought to successful completion

in July. The power house contains four units each of 18,500 h.p. under a 54 ft. head, with provision being made for a fifth unit for 1958 operation. This new capacity of 74,000 h.p. represents the prinicpal increase in hydro-electric capacity in Ontario in 1956.

At Caribou Falls, located on the English River near its junction with the Winnipeg River, preliminary construction was undertaken on the development of 102,000 h.p. in three units under a 58 ft. head for operation in 1958. An access road has been opened from Whitedog Falls, cofferdam construction is under way, and progress has been made in clearing the headpond area. In addition to a main concrete and earthfill dam about 1,260 ft. long and 80 ft. maximum height, four auxiliary dams will be required to close overflow channels.

At Whitedog Falls, on the Winnipeg River, about 30 miles north-west of the town of Kenora, good progress was achieved on preliminary construction towards the development of 81,000 h.p. in three units under a 50 ft. head. A 16 mile access road was built from the railway line near Minaki; also, a 115 kV transmission line from Kenora, to supply power initially for construction purposes. By December, the diversion channel had been completed and powerhouse excavation was under way. The power house and headworks will be incorporated in the main dam which will have a length of about 1,150 ft. and a maximum height of 110 ft. above the river bed. Initial service is scheduled for late 1957.

In addition to building new plants in the northwestern part of the province, where sharp increases in load are resulting from rapid growth in the mining and pulp-and-paper industries, it is planned to add for 1958 operation a new unit of 19,000 h.p. at Alexander Falls and one of 25,000 h.p. at Cameron Falls, both plants being on the Nipigon River.

In order to increase the output of stations on the English River, and incidentally those on the Winnipeg River in Manitoba, consideration is being given to a scheme for diverting water from the Albany River at Lake St. Joseph via the Root River into Lac Seul. In this matter, and in the operation of plants in the region, close liaison is being maintained with the Manitoba Hydro-Electric Board, an initial interconnection between the two systems having been completed in 1956.

Other Hydro-Electric Developments

Apart from the activities of the Commission, the Great Lakes Power Co. Ltd. is installing for early 1957 operation in its Upper Falls plant on the Montreal River a new unit comprising a 30,000 h.p. turbine driving a 25,000 kVA generator. The dam at this site had been raised 33 ft. to a height of 86 ft. above the river bed, and, as the average operating head will be 232 ft., the capacity of each of the two existing turbines is now rated at 12,650 h.p., representing an increase in plant capacity in 1956 of 1,900 h.p. for the two units. The Company also has undertaken the construction of a new plant at Centre Falls about five miles upstream from the river mouth at Lake Superior. A construction camp has been established and active work will be under way in 1957, with the plant of 28,000 h.p. in one unit under 115 ft. head scheduled for 1958 operation.

The Gananoque Electric Light and Water Supply Company is installing in its Jones Falls plant on the Rideau Canal an additional 1,500 h.p. unit under a 58 ft. head, to be completed during 1957.

Transmission and Rural Lines

During 1956, increases in the mileage of main transmission lines included 44 miles of 230 kV, 249 miles at 115 kV, and 130 miles at 13 to 44 kV. An additional 685 miles of rural distribution line were built.

Quebec

The Province of Quebec continued to maintain its leading position in hydro-electric development, with 514,300 h.p. of new capacity being brought into operation during 1956 and with active construction being under way towards developing an additional capacity of approximately 4,000,000 h.p. during the next five or six years in order to keep pace with growing industrial demands.

The Quebec Hydro-Electric Commission made good progress on its major project on the Bersimis River, the installation being completed of the first three units each of 150,000 h.p. in Bersimis No. 1, at the outlet of Lac Casse, and power being delivered to the new Bout de l'Ile substation on the Island of Montreal. The underground power house will have a total installation of 1,200,000 h.p. in eight units, of which perhaps three units will be completed in 1957 and the balance in 1958. At Bersimis No. 2, about 23 miles downstream, good progress was achieved on the preliminary stages of construction. The project involves some 60 miles of road, the excavation of a diversion tunnel about 1,100 ft. in length, the building of two dams—one of concrete and one of rockfill, and the excavation of an intake tunnel 4,000 ft. in length. The power house will have a total installation of 835,000 h.p. in five units, each turbine being rated at 167,000 h.p., under 375 ft. head.

At Beauharnois, on the St. Lawrence River, the Commission continued dredging towards the enlargement of the intake canal and has begun preliminary construction on the third and final section of the power house comprising 11 units each of 65,000 h.p. It is anticipated that initial operation will begin in late 1958 and that the plant will be completed in 1960, bringing total capacity of the whole development to 2,150,000 h.p.

Among other activities of the Commission, the third unit of 16,000 h.p. was brought into operation in November in its Rapid II plant on the upper Ottawa River and provision has been made for a fourth unit. In the field of transmission, the double circuit 450 mile 300 kV line from Labrieville to Quebec and Montreal was completed and placed in operation in October; also, work was begun on three additional 300 kV lines, Labrieville to Quebec City, Labrieville to Hauterive (near Baie Comeau) and a tie line between Bersimis plants Nos. 1 and 2. Studies and surveys are being carried out towards the development of the Lachine Rapids on the St. Lawrence River. Work was well advanced on the construction of a storage dam at the outlet of Lake Ste. Anne on the Toulnoustouc River, a tributary of the Manicouagan River, to allow a higher firm output from the plant of the Manicouagan Power Company in which additional capacity is being installed.

The Gatineau Power Company completed early in the year the installation of a new 60-cycle 47,000 h.p. generating unit in its Paugan Falls plant on the

Gatineau River, bringing total plant capacity to 285,000 h.p. New 15,000 kVA substations were built at Wyman and at Val Tetreau. Distribution lines were extended by 68 miles but the distribution system in the Napierville area was sold to Southern Canada Power Company.

The Shawinigan Water and Power Company has begun construction towards the development of 330,000 h.p. at Rapide Beaumont on the St. Maurice River about 10 miles upstream from La Tuque. The plant will comprise six 55,000 h.p. turbines operating under 125 ft. head and driving 45,000 kVA generators, initial operation being scheduled for the fall of 1958 and completion in 1959. To connect this plant with the Company's transmission system, an 87 mile 220 kV line will be built to the Three Rivers terminal station. During the year the Company's lines were extended by 75 miles at 220 kV from Chaudiere to Kinsey Falls, four additional miles at 220 kV, 42 miles at 110 kV, and 13 miles at 60 kV.

The Aluminum Company of Canada began preliminary construction, in the autumn, towards a new hydro-electric development on the Peribonka River at Chute des Passes about six miles below Passes Dangereuses dam. The power plant will take water from the Passes Dangereuses reservoir by means of a tunnel about seven miles in length. The installation will comprise five units each of 200,000 h.p. operating under 625 ft. head, being the largest turbines in Canada. Initial operation is scheduled for 1959 and completion of the 1,000,000 h.p. plant in 1960.

The Manicouagan Power Company is building an extension to their existing station at First Falls on the Manicouagan River, the undertaking being designated McCormick Dam Project No. 2. Plans call for the installation of three additional units each comprising a 60,000 h.p. turbine under 124 ft. head driving a 40,000 kVA generator. Operation of the first unit is scheduled for late 1957 and of the remaining two in early 1958, bringing the total plant capacity to 292,400 h.p. Power is to be supplied to the smelter now being built at Baie Comeau by the Canadian British Aluminum Company; the present 69 kV switching station is being extended and a new 161 kV transmission line 10 miles in length will be built to the smelter site.

Price Brothers Co. Ltd. has begun the construction of a new plant on the Shipshaw River, below Wilson Falls near the river mouth, which will contain a single unit of a 78,000 h.p. turbine under 255 ft. head driving a 70,000 kVA generator. The new plant is expected to be brought into operation in October, 1957, at which time the existing 10,100 h.p. plant at Murdock Falls will become inoperative. A short 69 kV line will be built to connect the plant with the Company's substation near Kenogami.

The Eastern Smelting and Refining Company Limited continued construction on its development on the Chicoutimi River at Chicoutimi which was begun in October, 1955, and is scheduled for operation in June, 1957. The new plant will contain a 42,000 h.p. turbine under 273 ft. head with a 40,000 kVA generator. The power will be supplied to the Company's nearby smelter by a one-mile 161 kV line.

The Town of Parent, Chapleau County, completed in November the first stage of a development on the Bazin River, about eight miles below the town, bringing into operation a unit of 1,300 h.p. under 30 ft. head. Provision has been made for a second similar unit to be installed at later date. Power is delivered to the town over a 6,900 V line.

Other power-producing agencies carried out extensions to their transmission and distribution systems. The Lower St. Lawrence Power Company completed a 35 mile 69 kV line between Rimouski and Trois Pistoles and is building new substations in Rimouski, Mont Joli and Matane. The Quebec Power Company completed a single circuit 66 kV 30 mile line between St. Pascal and Riviere du Loup and other smaller extensions. The Southern Canada Power Company built 14 miles of new 48 kV line and has under construction a 110 kV line between Magog and Bromptonville. The City of Sherbrooke built two miles of 46 kV line to supply a new pulp-and-paper plant in the city.

The Quebec Department of Hydraulic Resources, through its extensive system of storage reservoirs, successfully maintained regulation of the discharges of a number of important rivers for purposes of power production and flood control. Flood protection works were built on the Becancour and Bras Rivers. Preliminary studies were made of water powers of the Nottaway and Payne Rivers.

New Brunswick

The New Brunswick Electric Power Commission is continuing construction of its Beechwood development on the Saint John River with the first two units each comprising a 45,000 h.p. turbine under a 60 ft. head driving a 40,000 kVA generator, scheduled for completion in December, 1957, and with provision for a third similar unit. The Commission completed in November the addition of a new unit of 22,500 kW capacity in its steam plant at Chatham while its 875 h.p. diesel plant at St. Quentin was dismantled in October.

During the year, a total of 158 miles of 69 kV main transmission line and 185 miles of rural distribution lines were completed leaving under construction at the end of the year 100 miles of 138 kV main line from Beechwood to Grand Lake and 47 miles of similar line from Newcastle to Bathurst. New substations included a 40,000 kVA station at Moncton Terminal and a 10,000 kVA installation at Dalhousie.

Nova Scotia

The Nova Scotia Power Commission is expecting completion, early in 1957, of its Bear River plant at Bear River with one 5,300 h.p. turbine under 142 ft. head operating a 5,000 kVA generator. Investigations are proceeding with respect to the Commission's proposed Wreck Cove development in Cape Breton Island. During the year, extensions to the transmission system included 51 miles of main line, mostly of 69 kV capacity, and 100 miles of rural distribution lines. In addition, 120 miles of transmission line of various capacities are presently under construction with completion of individual extensions expected during January and February, 1957.

The Nova Scotia Light and Power Co. Ltd. is actively considering the addition of an estimated 5,000 h.p. capacity at its Hemlock Falls development on the Avon River at Windsor Forks to be completed late in 1958. The two 1,150 h.p. horizontal units at

(Continued on page 112)

The Economics of Pumped Storage

In this section of his article, Dr. Charles Jaeger discusses such matters as runner efficiencies, new types of runners, the general layout of pumped storage systems, mixed systems and tidal schemes, and gives his general conclusions

PART TWO

Runner Efficiency—New Types of Runners

The efficiency η'_T and η'_P of the generating and of the pumping set are of great importance as the overall efficiency is proportional to their product.

It appears that for peak-load stations, which will have to work under rapidly varying load conditions ($n' < 4$ or even $n' > 4$ if the maximum power is not reached regularly during the period t_T), the runner must have a flat efficiency curve. A flat efficiency curve is always desirable, and it is of paramount importance for peak-load stations and even more so for pump-storage schemes.

When considering the efficiency of a turbine and the necessity to produce a given power N, the energy losses can be shown to be proportional to

$$\int \left(\frac{v}{\eta'_T}\right)^3 dt \qquad \ldots(18)$$

that is, the lower the efficiency η'_T, the higher the discharge required for producing the energy and the higher the energy losses in the pipes which will be proportional to (v/η'_T).[3] This formula shows the paramount importance of a high flat efficiency curve.

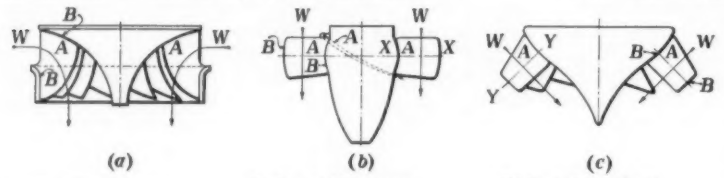
The Kaplan turbine is known for its high flat efficiency curve, and a Kaplan-type axial-flow pump-turbine with movable blades is a very desirable proposal for low-head pumped-storage schemes.

It seems that the range of heads for an axial pump-turbine is even more restricted than the limited range of an ordinary Kaplan turbine and does not exceed 30 ft. This explains the fundamental importance of the new mixed-flow runners with movable blades recently developed by Mr. P. Dériaz, Chief Water-Turbine Designer of The English Electric Co. Ltd. [9, 10]

Three different types of machines are being developed on the same principle of mixed-flow variable-pitch runners.

(a) The Dériaz mixed-flow variable-pitch (reaction) turbine (Fig. 6);

(b) the equivalent runner for a pump, and



(a) (b) (c)

Francis turbine runner
Inception about 1870 (Swain)
A=fixed vanes; *B*=toroidal surfaces of hydraulic profile. *W*=direction of flowing water: radially inwards, axially outwards.

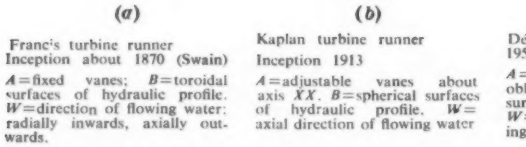
Kaplan turbine runner
Inception 1913
A=adjustable vanes about axis *XX*. *B*=spherical surfaces of hydraulic profile. *W*=axial direction of flowing water

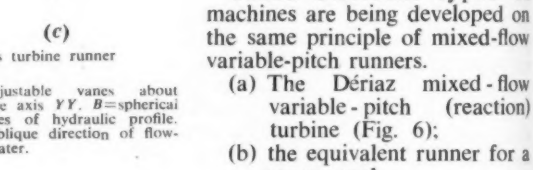
Dérias turbine runner
1952
A=adjustable vanes about oblique axis *YY*. *B*=spherical surfaces of hydraulic profile. *W*=oblique direction of flowing water.

Fig. 6 (above). Compared shapes of runners

Fig. 7(a) (below). Dériaz pump-turbine runner model with vanes open

Fig. 7(b) (right). Dériaz pump-turbine runner model with vanes closed





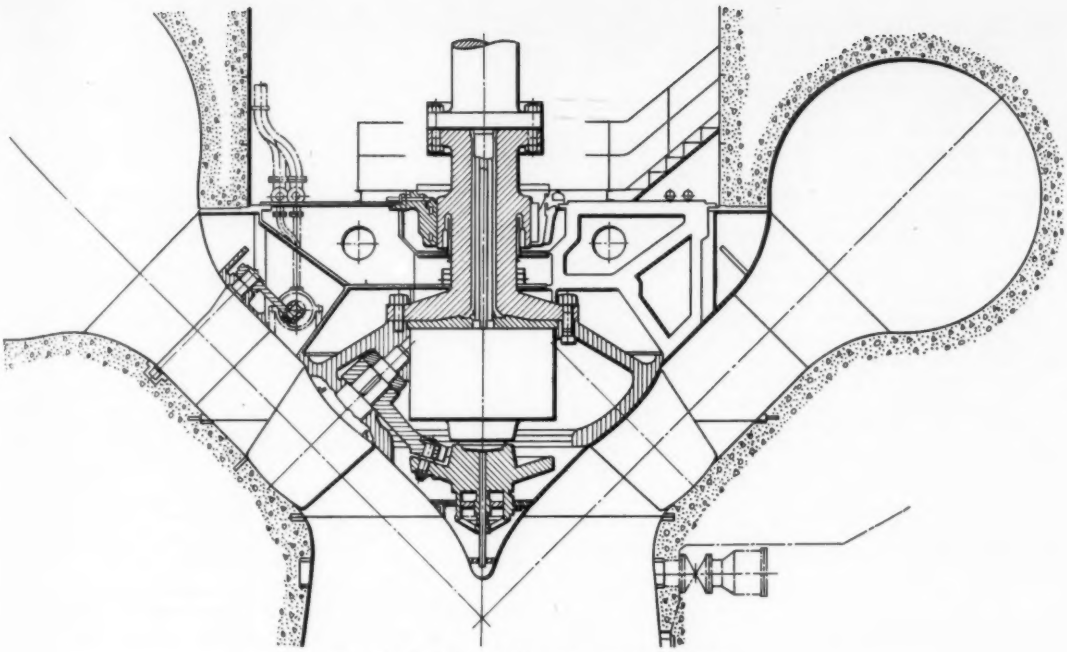


Fig. 8. Section of Niagara pump-turbine

(c) the Dériaz mixed-flow variable-pitch reversible pump-turbine (Figs. 7, 8).

In a recent correspondence[9] with the Institution of Civil Engineers, the designer of the Niagara Falls reversible pump-turbines, Mr. P. Dériaz, lays down his experience as follows*:

"The origin of the mixed-flow variable-pitch reversible pump-turbine, now being installed at Niagara Falls, is well worth mentioning. Early in 1952, it was noticed that some of our largest Francis turbines were run day in and day out at very low gate opening with consequent wastage of water. The possibility of disturbances on the extensive distribution network made it necessary to provide for emergency power supply at the very shortest notice and this was the reason put forward by the operating engineer for this unorthodox procedure. To the designer of the turbines, this condition was very disappointing. To remedy this state of affairs would require a turbine having its maximum efficiency at small gate opening instead of the usual $\frac{3}{4}$ of full rated load for a Francis turbine of medium specific speed. By referring to Fig. 9 it will be seen that the Kaplan turbine approaches this requirement. On the other hand, the Francis turbine of medium specific speed (N_s=50) gives at 4/10ths of rated power an efficiency 10 points below the Kaplan of N_s=125. The shaded area illustrates the importance of the improvement required. The diagram also shows why the Kaplan turbine has ousted the propeller fixed-blade turbine in so many cases. Now it is particularly the Francis turbine, associated with storage, short pipelines and heads ranging from 200 to 700 ft., which is interesting.

"It was in 1952 that the writer set himself the task to investigate the possibilities of applying the principle of the Kaplan turbine with its feathering vanes to a head of 300 ft., i.e., well in excess of anything that was attempted so far. The Kaplan turbine to date is developed to a maximum head of 200 ft. Attempts to exceed this head meet with very serious difficulties:

(a) A lower specific speed is necessary than that of a normal Kaplan turbine because of cavitation conditions and better efficiency. The hydraulic requirement of a lower specific speed is the short expanse in a radial direction of the inlet edge of the turbine runner vanes. As compared to a Kaplan runner, there must be an increased number of vanes and an increased ratio of vane length to pitch. This leads forcibly to the mixed flow layout, Fig. 6c.

(b) Mechanically the enormous loads to be supported by the runner-vane pivots require a very large hub diameter, to locate large bearings.

It became obvious for all these reasons that the axial flow character of the Kaplan turbines, Fig. 6b, had to be abandoned and that the mixed-flow position of the Francis runner vane, Fig. 6a, associated with the feathering possibility for altering the pitch, provided the solu-

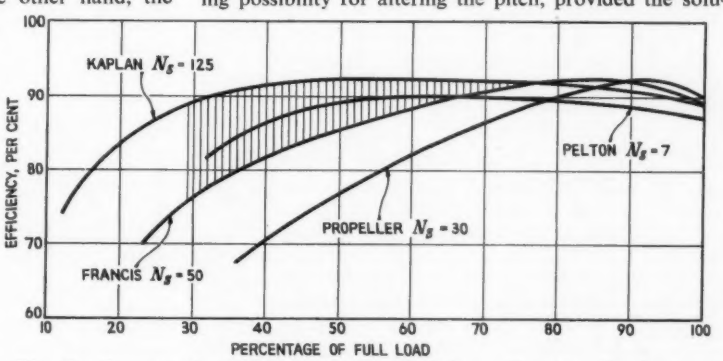


Fig. 9. Compared efficiency curves of Pelton, Francis, Kaplan and Propeller turbines

* Quotation from a memorandum partly reproduced in the Proc. Inst. Civil Eng. Hydraulics Paper No. 10. 1956.

tion. The new turbine thus conceived is shown in Fig. 6c. Its principal features are as follows:—

(1) The oblique "mixed-flow" position of the runner-vane trunnions, with the advantage of the short radial expanse in the vane inlet edge, associated with larger distances between the bearings of the vane trunnions.
(2) The spherical surfaces of the hub and skirt to permit rotation of the vanes while maintaining close clearances (a departure from the corresponding toroidal surfaces of the Francis runner).
(3) The runner vanes are of simpler shape than those of the Kaplan and can be made to close over their entire length, where they meet each other in the closed position, where the runner acts as an effective shut-off valve, no wicket gates being provided.

"A turbine designed on those principles (see Figs. 7 and 8) and tested gave remarkable results, the efficiency curve showing an improvement even on the Kaplan turbine (Fig. 9). There is no doubt that such a turbine has many striking advantages over the Francis which it will replace in many cases as the Kaplan has replaced the fixed-vane propeller runner."

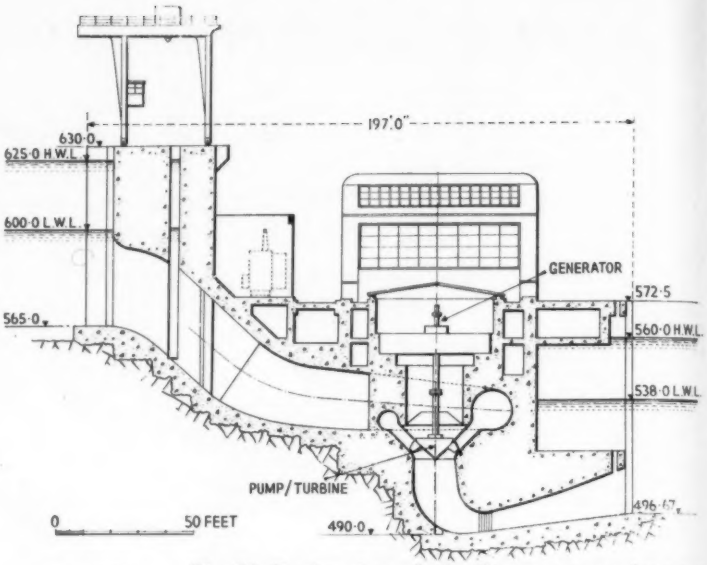


Fig. 10. Section through the Niagara pumped-storage station showing the extremely compact layout obtained with a reversible Dériaz pump-turbine

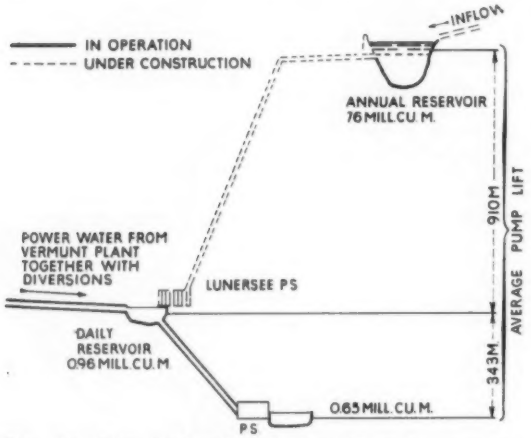


Fig. 11. The Rodund and the Lünersee pumped-storage schemes of the Voralberger Illwerke (according to A. Ammann, 5th World Power Conference)

Suppose that in a certain period of time t_T the use of a Dériaz turbine would show an efficiency improvement of 9 points on a conventional Francis turbine according to the formula

$$N = \eta_T Q_T (H - \Delta H)$$

there is not only a net gain of 9 per cent. on η_T but an additional reduction of ΔH by the factor $\frac{1}{(109)^3} = \frac{1}{129{\cdot}5}$ or about $100 - 77{\cdot}3 = 22{\cdot}7$ per cent. For power developments with long tunnels and/or pipes, this remark may be of fundamental importance. The convenient choice of the runner may considerably influence the overall efficiency and economics of a pumped-storage scheme.

Designs for Dériaz turbines are now being developed for heads up to about 700 ft. as against about 200 ft. for the Kaplan and 30 ft. for an axial-flow pump[11].

The development of pumps with movable blades is about to start in parallel with tests on turbines.

The most striking example of the versatility of the new design is certainly the Niagara Falls reversible-mixed flow pump-turbines with movable blades, designed for the Sir Adam Beck No. 2 station of the Hydro-Electric Power Commission of Ontario. In the

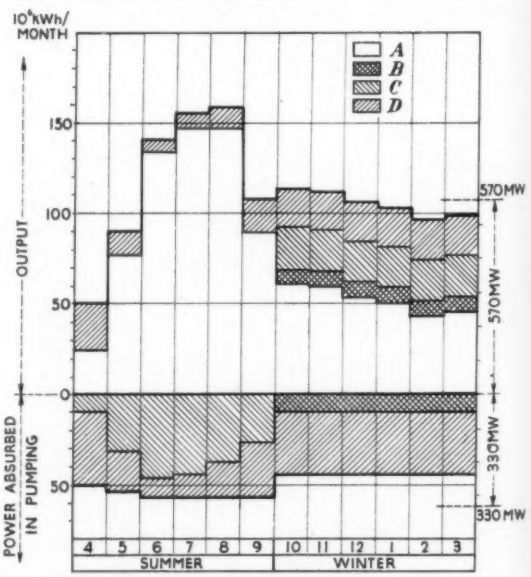


Fig. 12. Energy and power diagram of the Ober Ill-Lünersee pumped-storage stations (according to A. Ammann)

TABLE VI—DATA ON TYPICAL PUMPED-STORAGE SCHEMES

Station	Generating Sets	Pumping Sets	Upper reservoir	Lower reservoir
Ill-Rodund daily storage	170,000 kW, 4 sets H = 343 m. Q = 60 cu. m. per sec. 40,000,000 kWh per annum total efficiency η = 65%	4 sets H = 343 m. Q = 38 cu. m. per sec. 64,000,000 kWh per annum	960,000 cu. m.	685,000 cu.m.
Ill-Lünersee yearly storage	5/6 sets 187,000 to 217,000 kW H = 978 m. Q = 26 to 36 cu. m. per sec. 1,331,000,000 kWh including Rodund	5/6 sets 212,000 to 253,000 kW $H \simeq$ 910 m. Q = 19 to 22 cu. m. per sec.	76 × 10^6 cu. m.	960,000 cu. m.
River Our daily storage (first stage development)	320,000 kW, 4 sets H = 280 m. Q_0 = 144 cu. m. per sec. 4 hours per day 1360 hours per annum 435,000,000 kWh per annum total efficiency 66%	215,000 kW, 4 sets $H \simeq$ 280 m. Q_0 = 64 cu. m. per sec. 9 hours per day 3060 hours per annum. 600,000,000 kWh per annum	2,300,000 cu. m Dam: L = 2330 m. h = 14·3 m. penstock: L = 570 m. dia. = 6·2 m.	2,300,000 cu. m. Dam: L = 100 m. tunnel: L = 250 m. Area = 75 sq. m.
River Our (second stage development)	640,000 kW H = 280 m. Q = 288 cu. m. per sec.		4,600,000 cu. m.	
Niagara Falls daily storage	207,000 kW, 6 sets H = 13-27 m. *Sir Adam Beck Station No. 2* 1,170,000 kW H = 89 m. Q = 1140 cu. m. per sec.	207,000 kW, 6 sets H = 15-27 m.	18,350,000 cu. m.	Intake canal to Sir Adam Beck
Ffestiniog daily storage	300,000 kW, 4 sets H = 302 m. to 324 m. 4 hours 5 days a week 300,000,000 kWh per annum load factor 0·114	248,000 kW, 4 sets H = 302 m. Q = 68 to 76·3 cu. m. per sec. 7 hours 5 nights a week	1,700,000 cu. m. 2 vertical shafts: L = 1372 m. dia. = 4·4 m. 2 tunnels: L = 719 m. dia. = 3·1 m. 2 tunnels: L = 500 m. dia. = 2·6 m. 2 pipes: L = 152 m. dia. = 2·3 m.	
	Cost £12,000,000 or £40 per kW. Transmission £7·5 per kW			
Sron Mor (Glen Shira) yearly storage Clachan Power Station	5000 kW, 1 set H = 42·1 m. Q = 14·75 cu. m. per sec. turbine efficiency 85% 40,000 kW H = 293 m. Q = 17·8 cu. m. per sec. Annual load factor for the two stations α = 0·20	5,100 kW, 1 set H = 43·6 m. Q = 10·3 cu. m. per sec. pump efficiency 83%	21,300,000 cu. m.	1,560,000 cu. m.

Niagara Falls scheme, variation in the upper reservoir and tailrace levels cause the operating heads to fluctuate between approximately 50 ft. (15 m.) and 90 ft. (27 m.) when pumping and 43 ft. (13 m.) and 90 ft. (27 m.) during generation. The Dériaz reversible-blade pump-turbine is stated to secure high efficiencies under all operating conditions.

General Layout of Pumped-storage Schemes and Examples (see Table VI)

The equation (6) giving the overall efficiency ρ_1 of a pumped-storage scheme points to some possible classification of this type of scheme.

True pumped storage corresponds to the case $Q_T = Q_P$ and $H_T = H_P$. This is likely to be dearer than other types, as the whole capital cost of the plant (dams, tunnels) is to be paid off by pumping. Nevertheless, several examples of powerful pumpage stations of this type have been built in recent years or are now under consideration (Lac Noir in the French Vosges, Our River scheme in Luxembourg, Ffestiniog in Wales). It is to be expected that this type of development will be restricted to schemes with short tunnels and pipes, and most of them will be low or medium-head schemes located as near as possible to industrial centres. If conditions are favourable, the capital cost for civil-engineering plant may not be more or may be even less than the cost of the electro-mechanical plant. The River Our pumping scheme (Luxemburg) located in the very centre of a highly industrialised country with coal mines at proximity in the Saar and the Ruhr, is an exceilent example of this type of development, and a proof that it can be economical. In his comments to the paper by Messrs.

Fulton, Haldane and Mountain*, Mr. Logan Kerr expressed the opinion that low-head schemes (probably mostly of the free pumped-storage type) are the most likely to be developed in the United States. He mentions seven schemes with heads less than 250 ft. and two schemes with heads higher than 700 ft. now under consideration. The possibility of using coastal hills (Fig. 3) for installing pumped storage near large towns should be investigated. The possibility of pumping water between two large reservoirs located on the same river is also a most promising possibility.

For heads of less than 300 ft. the reversible pump turbine is likely to be the correct solution.

Mixed Pump Storage (see Table VI)

Even better financial results may be obtained with mixed pumped storage when either $H_T > H_P$ and/or $Q_T > Q_P$. Usually both conditions will be combined in one work. A typical low-head scheme of this type is the Niagara Falls scheme or the Sron Mor pumping station. At Niagara, the pumped water will be used first on a head of 53 ft. to maximum 90 ft. passing through the reversible pump-turbines and then through the 292 ft. high head of the Sir Adam Beck Station No. II. Niagara is a daily storage scheme. The Sron Mor pumping station of the Glen Shira scheme is a combined (yearly) seasonal and daily storage, as water can be pumped up 143 ft. from a lower small reservoir with large catchment area to a large upper reservoir with small catchment area and then used on a total head of 143 + 940 = 1,103 ft. The Austrian power stations on the River Ill are excellent examples of medium and high-head schemes. The Rodund Ill power station has a daily reservoir and transforms cheap night energy into valuable peak-load energy. The Lunersee-Ill station under construction on the same development will have a large reservoir for storing water over long periods of time. There are many other high-head yearly storage schemes in the Alps, as the Etzel scheme in Switzerland, the Herdecke and Witznau schemes in Germany and many others.

In all these cases the economics of the pumping stations must be analysed in conjunction with the cost of energy generation in the whole development of which they are an integral part.* A financially very interesting alternative of mixed pumped-storage is the case of a pumped-storage station being added to an existing hydro-power plant already under running conditions and paying-off without storage.

When pumps alone are installed, with no increase in the turbine capacity and no major changes being required in the water conduits, then the pumping may result in a profitable transformation of cheap (night) off-peak energy into more valuable (day) on-peak energy or into a greater accumulation of dear winter energy at the expense of less valuable summer energy. But the installed capacity of the turbines remains unchanged.

As the whole costly civil-engineering plant is already there, the additional cost for installing the pumps is relatively low and the whole operation is a profitable one. A typical example of this procedure, which is likely to become popular in the Alps and similar regions, is the high-head Etzel pumping installation.

Extending an existing power station by adding both to the pumping capacity and to the generating capacity is a more difficult proposal. When investigating existing power stations for possible enlargement on these lines it is usually found that some technical details are in the way of an improved modernised design. Either one of the required storage reservoirs, usually the lower, is too small for the required volume of water to be stored or pumped, or the existing pressure tunnel is too small, causing excessive pressure losses and correspondingly high operating charges, if the generating capacity is to be increased (see previous article); or the surge tank may be too small or badly located, causing dangerous conditions either for transient or for steady flow. Ways and means can be found to enlarge or modify existing surge tanks.[15,16]

When new power stations are being designed their

* Messrs. Fulton, Haldane and Mountain[17] estimate the capital cost of the installed kW to be less than £40 for pumped storage in Great Britain. For steam power the equivalent figure is £65 per kW installed, not including transmission lines.

* A. A. Fulton, T. G. N. Haldane and R. W. Mountain comparing Ffestiniog to other schemes write that[17] appreciably lower costs per kW are anticipated for mixed pumped storage contemplated in Scotland.

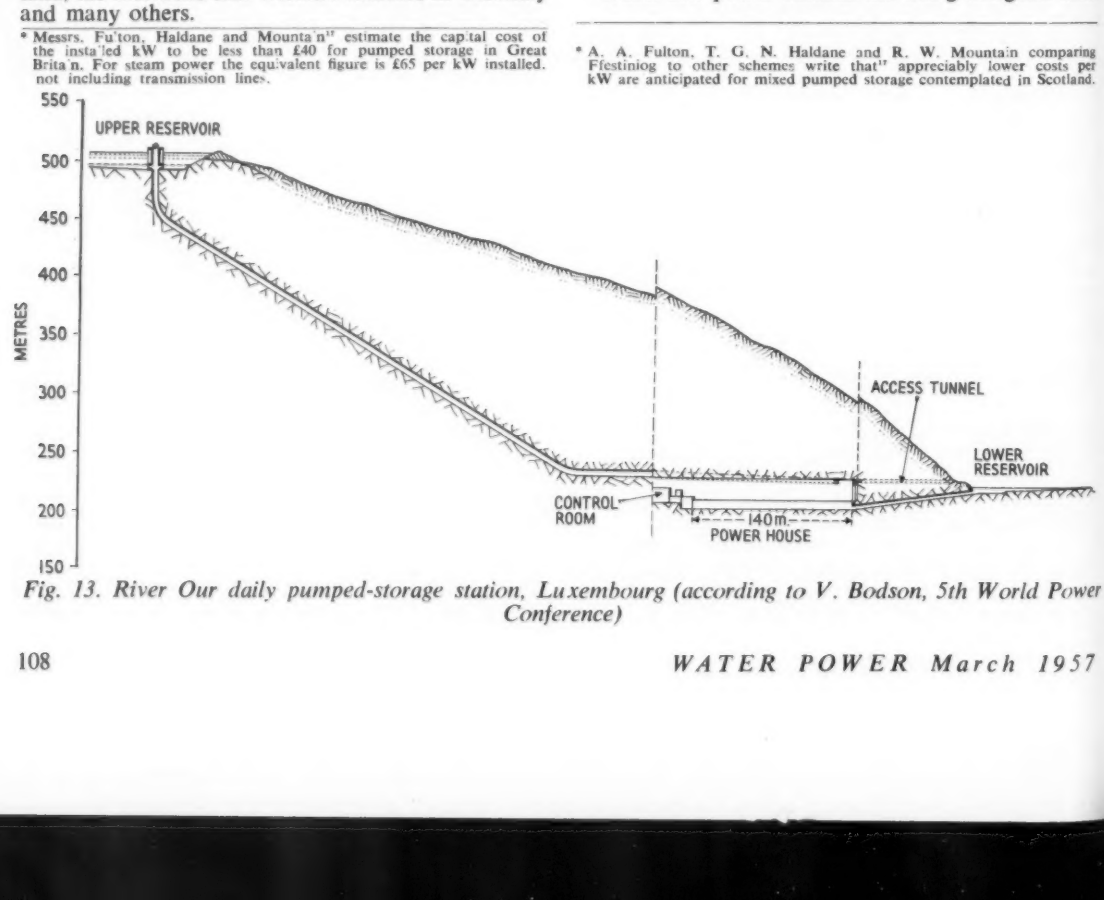


Fig. 13. River Our daily pumped-storage station, Luxembourg (according to V. Bodson, 5th World Power Conference)

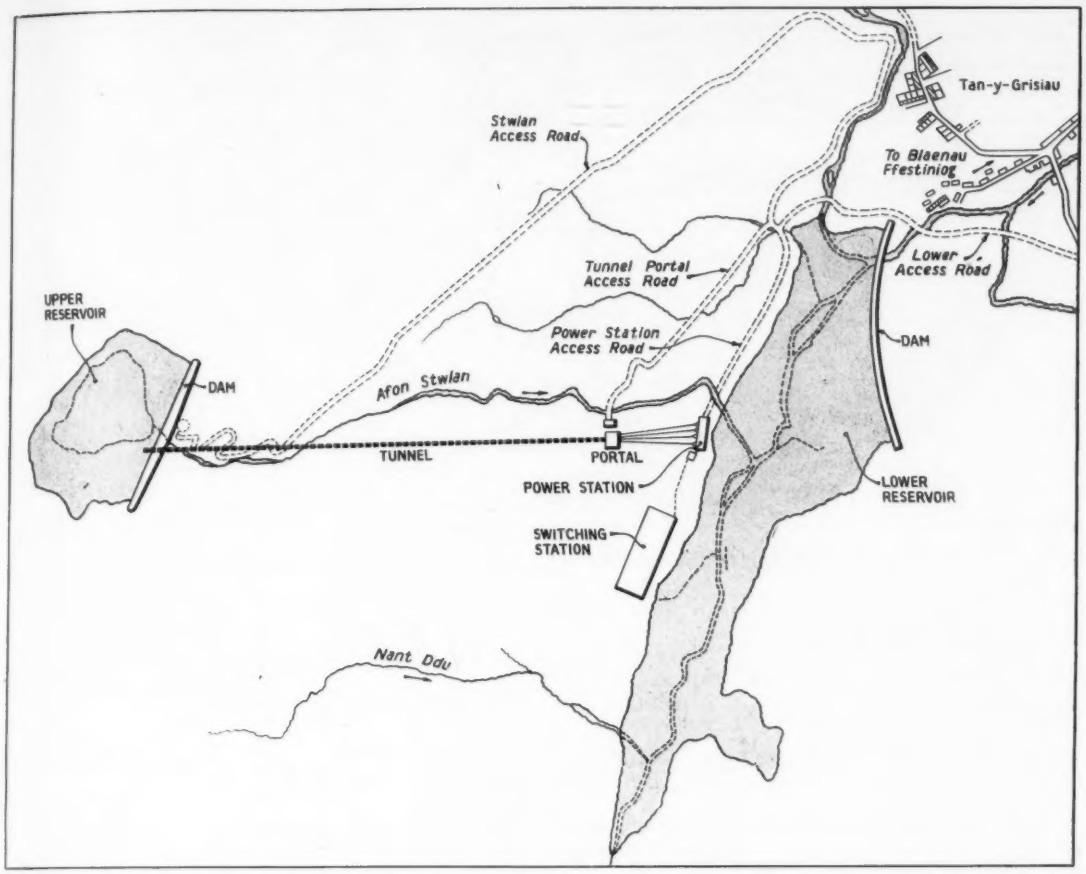


Fig. 14. Sketch map of the Ffestiniog scheme in North Wales (according to V. G. Newman, BEAMA Journal)

possible future enlargement with additional pump-turbine sets should be considered. At the design stage, this may be possible without undue additional expenses, by correct dimensioning of the compensation basin, the tunnel and surge tank.

When the power house is at the toe of a dam, future extension of the power house should be considered and if necessary the intakes for future additional pump-turbine sets should be foreseen at an early stage. Pumping between two yearly reservoirs separated by a dam about 300 to 600 ft. high is the cheapest possible way of developing peak power.

In all these cases it is being considered how a pumping station can be added to an existing hydro-power scheme. It is not impossible to visualise the opposite case where a pumped storage scheme with relatively small dam and small reservoir would be installed first, for producing daily storage and stand-by capacity, the construction of an expensive dam for accumulation of water over longer periods (yearly storage) being considered only at a second stage of the development.

Several developments (River Our Fig. 13, Ffestiniog Fig. 14, Gosausee in Austria Fig. 15) have been constructed with underground power stations. One of the main advantages of this technique is to allow for the pump axis to be located at the required low level for avoiding cavitation, in spite of the drawdown in the lower reservoir. A similar arrangement can be recommended for equipment of coastal hills, as illustrated in Fig. 3.

Pumped Storage and Tidal Schemes

The danger of coal production failing to meet demands in a not too distant future have again directed the attention of some planners to tidal schemes. Electricité de France have decided to start work on the Rance scheme in autumn 1956. It is expected that the same authority will resume the studies on the far larger Mont Saint Michel tidal projects. But general economical factors only partly explain this renewed interest in tidal power. Fundamental technical improvements in the design, permitting lower energy prices, are also responsible for this trend.

In the past, most tidal schemes were designed as single-tide, single-dam projects, producing energy at a variable rate. With such designs there are always long periods during the day when no energy is being produced; no firm capacity is thus available. This requires an equivalent capacity of steam or hydro power to be on tap as standby somewhere on the grid. When analysing the economics of the supply system, the cost of tidal energy must be charged with the additional cost of this standby capacity.

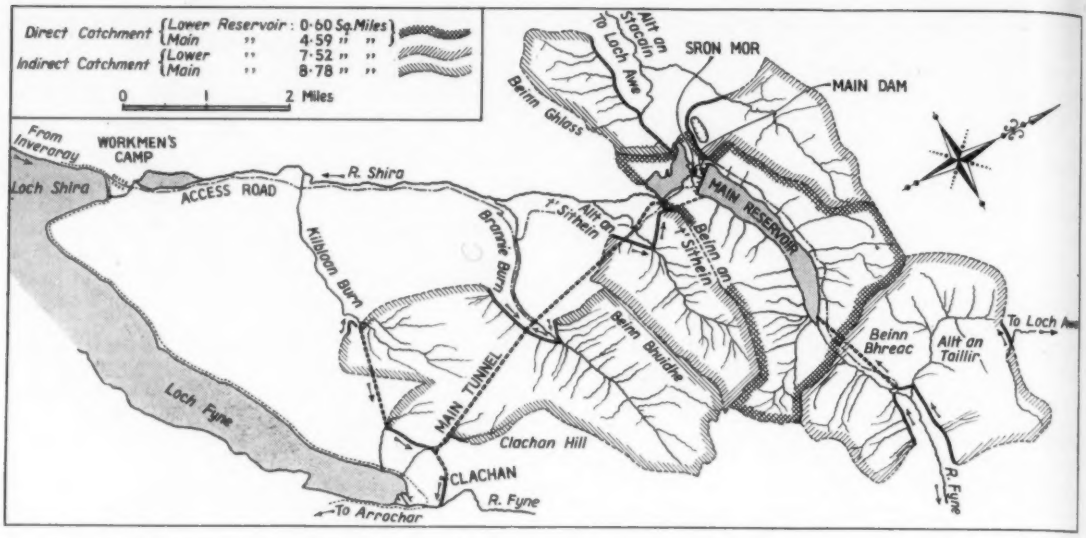


Fig. 15. Map of Glen Shira scheme, showing location of Sron Mor pumped-storage station

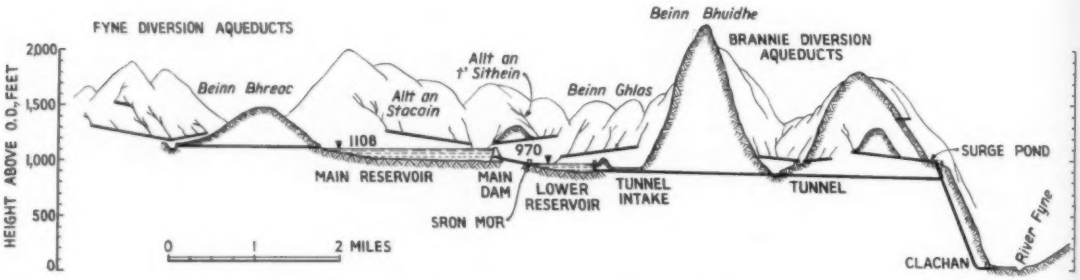


Fig. 16. Hydraulic section of Glen Shira scheme

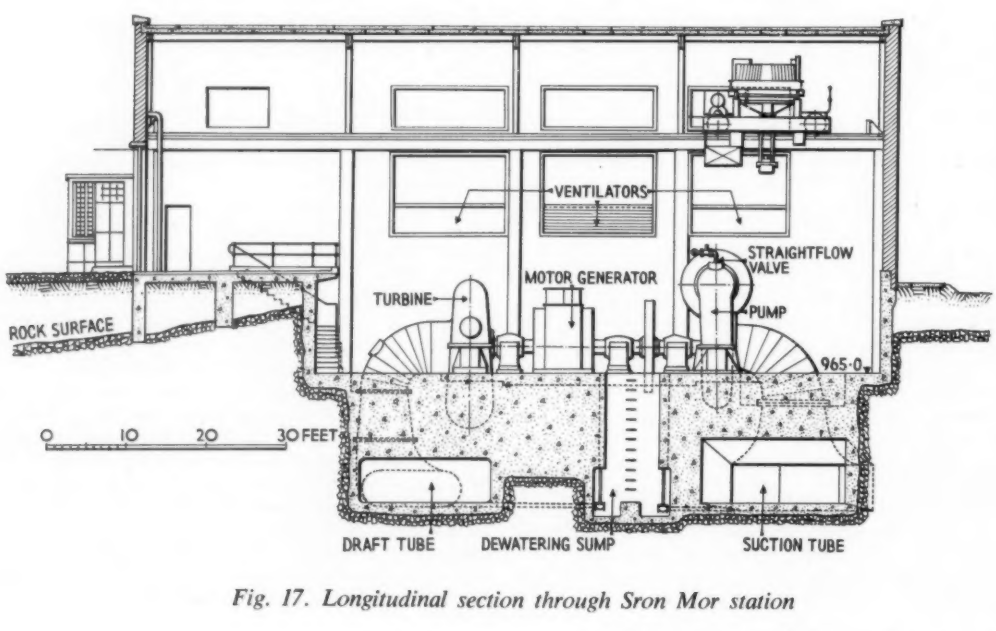


Fig. 17. Longitudinal section through Sron Mor station

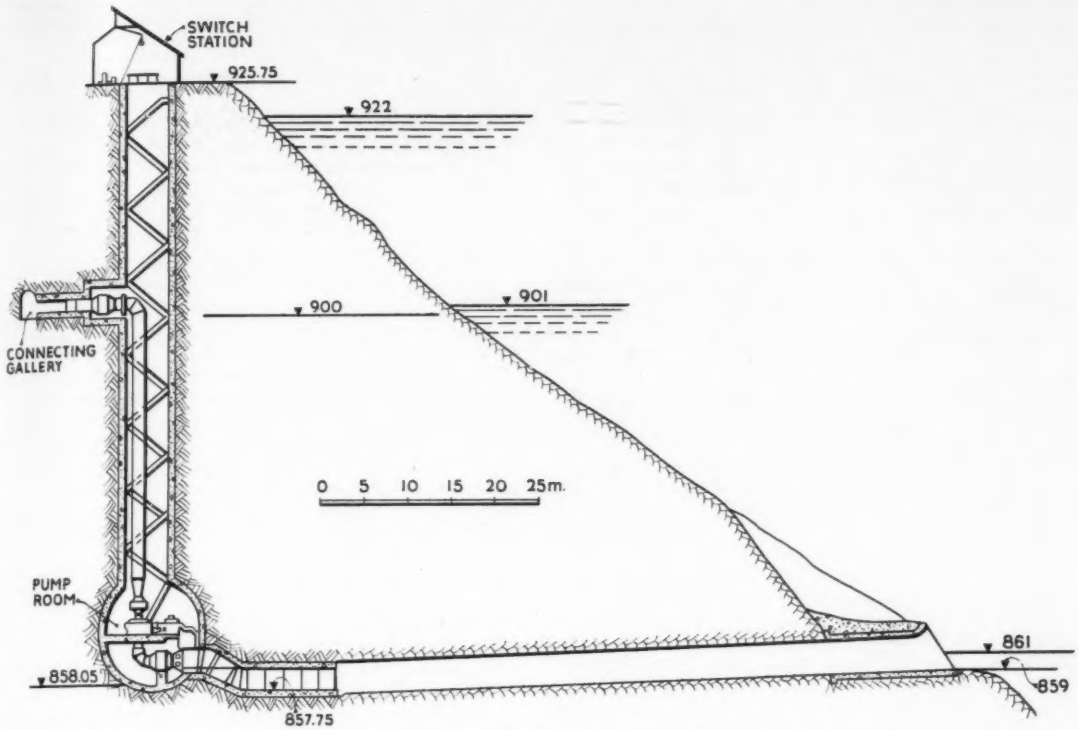


Fig. 18. Cross section of the pumped-storage station of Gosausee (according to K. Willmann, 5th World Power Conference)

The latest French tidal schemes are based on a new turbine design; the reversible axial-flow pump-turbine (Kaplan type) for instance, permits double-tide working on a single-dam project, both ebb and flood tides being used for energy generation. In addition, the runner can be operated as a pump and the level in the reservoir can be raised above tide level. The analysis of the possible power cycles shows that a tidal scheme can be used as its own pumped-storage scheme and that a certain amount of firm capacity can be guaranteed.

The Rance tidal scheme, as described by R. Gibrat, will have an installed capacity of 342,000 kW, a firm capacity of 140,000 kW guaranteed during the daily working hours and a guaranteed capacity of 280,000 kW during a shorter peak period. The French hydro-power system has enough standby capacity to balance the excess capacity installed at this projected plant.

When the 1945 Severn project was discussed some years ago, it was estimated that the required standby capacity (possibly pumped-storage capacity) would be too expensive. This conclusion should be revised. The Rance design shows how firm power capacity could be secured at the Severn and additional power could be got from pumped-storage at a realistic price.

Considerable amounts of energy and power are to be got from tidal schemes. The Severn is estimated to be at least 800,000 kW; the Saint Michel scheme at about 10 to 15,000,000 kW, and probably as much again for the Minquiers project. These are projects which could match the demand for more power in the future; they can hardly be tackled by one nation alone and should become the common interest of a group of nations.

Conclusions

The analysis of the rising demand for more electric power and more energy and of the probable development of the production shows that the energy gap, mainly the "coal gap," will widen in the near future in Western Europe. Considerable efforts are being made to accelerate the production of nuclear power, and tidal projects, which were shelved a few years ago, are being reconsidered. Increased energy production is indispensable if western civilisation is to take advantage of the new rapidly developing technical revolution. It is even more indispensable if the "West" is to produce the tools and the machines wanted by the lesser-developed countries.

The problem of installed capacity and peak power is not less acute than the basic problem of energy production. Pumped-storage does not create energy, but it stores energy and transforms base-load energy into indispensable and more valuable peak-load power. Consequently it permits a better utilisation of all sources of steady power; hydro power (run-of-river stations), steam and nuclear power, and possibly tidal energy. The analysis of the economics of pumped-storage shows it to be a sound proposition.

Recent developments in pump and turbine design, especially for low and medium heads, the high runner efficiencies which can be guaranteed at any gate opening likely to occur under normal running conditions, are of great importance. It is to be expected that low-head schemes near to industrial centres will

be more numerous in future.

The possibility of developing mixed pump-storage schemes, by superimposing pumping to a more conventional hydro-power scheme, should be kept in mind when designing new developments. It was shown how difficult it is to introduce the pumps afterwards, when no provision had been made for this extension. The development of the new axial-flow reversible-pump turbine revolutionises the economics of tidal power.

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this station have been replaced by a single runner rated at 5,000 h.p. Also under study is an estimated development of 4,000 h.p. on the Nictaux River at Alpena. The Company's 360 h.p. development on the East River at Chester, presently out of service, is to be dismantled in the near future. Expansion of the Company's steam plant on Water Street, Halifax, is continuing with a new 45,000 kVA unit scheduled for operation in 1957 and another similar unit to be added in 1959.

Twenty-four miles of 69 kV main transmission line were completed during the year as well as 13 miles of rural line. Additions of 13,500 kVA and 150,000 kVA respectively were made to substations at Imperial Oil and Tufts Cove. A 100,000 kVA addition is under construction at the Water Street substation in Halifax as well as smaller additions at the Armdale and Young Street substations, and a new substation at Walton.

The Seaboard Power Corporation has under construction a 20,000 kVA substation at Sydney scheduled for completion later in 1957.

Newfoundland

Union Electric Light and Power Co. Ltd. completed its plant on the Trinity River near Trinity, comprising a 2,000 h.p. turbine under a 260 ft. head driving a 1,875 kVA generator. A second unit, having similar turbine and generator capacities, is under active prospect. Transmission lines under construction include 33 miles of 48 kV line between Lockston and Clareville and 20 miles of 13·8 kV line between Bonavista and Kings Cove.

The United Towns Electric Co. Ltd. completed in December the installation of a 5,600 h.p. turbine, at 275 ft. head, and a 5,000 kVA generator at its new plant on New Chelsea Brook at New Chelsea. Transmission lines were extended by 16 miles of 66 kV line from New Chelsea to Hearts Content and 16 miles of 33 kV line from Avondale to Whitbourne.

Bowater Power Co. Ltd. is constructing, for operation in 1957, a plant located on the Corner Brook River at Corner Brook comprising 12,000 h.p. in two units including two 5,100 kVA generators.

The Maritime Mining Corporation expects to complete in February, 1957, a new plant on the Venams Brook at Green Bay with a 500 h.p. turbine under a 262 ft. head operating a 480 kVA generator. Another new plant at Snooks Arm, Green Bay, to comprise an 850 h.p. turbine under a 273 ft. head, and a 700 kVA generator, is presently under construction.

The Newfoundland Light and Power Co. Ltd. has under active prospect the construction of two plants on the Rattling Brook near Norris Arm, the first to comprise an estimated 13,000 h.p. in two units under a 200 ft. head and the second, about 3,100 h.p. with a head of 125 ft. The Company completed in July the installation of an additional unit of 10,000 kW in its steam plant at St. John's. Seven miles of transmission line were completed between Corner Brook and Benoits Cove.

In Labrador, the British Newfoundland Corporation completed investigations on the Hamilton River which proved that the development of the power site at Grand Falls, one of the largest untapped sources of hydro-electric power in the world, is feasible. During the year, a road was under construction along a 100 mile stretch between the Quebec North Shore and Labrador Railway and the power site.

Direct Air Compressors. Mackay Industrial Equipment Limited have issued a brochure to describe the portable direct air compressor they manufacture. This machine (Model DAC 130) is capable of delivering 132 cu. ft. per min. at 90 lb. per sq. in. (3·74 cu. m. at 7 kg. per sq. cm.) and is claimed to combine efficiency with supreme simplicity. No flywheel is necessary as the compressor is a free-piston machine with opposed cylinders, one of which delivers the air direct to the receiver while the other stores the necessary energy for the return stroke.

Book Reviews

Water Power Resources of Yugoslavia. Vol. I. Obtainable from The Yugoslav National Committee of the World Power Conference, Dečanska 14/III, Beograd, Yugoslavia. 1956. 13¾ in. × 9¾ in. × 1½ in. Cloth board covers. 455 pp. 251 ff., plus folding plates. Bilingual edition with full text in English and Serbo-Croat; brief summaries in French, Russian, Spanish, German and Italian. Price $25.

Yugoslavia possesses economically exploitable hydro-electric resources estimated to be capable of producing an output of 60,000 million kWh per annum, of which little more than 3% have yet been harnessed. The relation between the power consumption *per capita* of a country and the material well-being of its peoples is now accepted as axiomatic, and it is for this reason that the authorities of Yugoslavia have been making a scientific and technical assessment of their national energy resources; in these resources water power would seem to play a predominant part although other sources of power—e.g. coal, petroleum and natural gas—are also being investigated .

The present volume is divided into two parts, the first dealing with the investigational methods used in assessing the power resources, and the second giving an account of the hydrology, topography and other characteristics of each individual drainage area.

The methods of assessment exhibit no departure from what can now be regarded as conventional practices and take into account such considerations as the location and time sequence of a plant, the flow regime, control and storage problems, the interconnection of adjoining run-off areas and so on, together with an estimate of the power potentialities of the stream courses, taken section by section.

The data given are essentially of a basic nature as detailed studies of the more important watercourses are to be undertaken shortly with a view to the selective development of actual schemes. Still, a remarkable amount of information is given, as general data on precipitation, gauging, seasonal discharges, etc., have been collected over a number of years and are now published for the first time. These data have been collected by the Federal Hydrometeorological Service and the Institute of Hydraulic Engineering, hydrographs being given for many observation stations dating back to 1923 while other records are for even longer periods.

In the section devoted to the actual power resources the summarised results are given of close studies which have been made on 26 separate catchment areas by the Institute of Hydraulic Engineering, Belgrade. Each area is considered from four aspects; (a) its situation, size and shape, and with reference to such matters as elevation, precipitation, isohyetal lines, gauging stations, geological characteristics, vegetation, the main river and its chief tributaries; (b) data regarding watercourses — the slopes, discharges, run-off coefficients and water regime; (c) the fundamental water-control problems, with special reference to their economic influences; (d) data on the actual power resources estimated in accordance with the methods discussed in Part I of the volume.

The book is handsomely produced, the paper and printing being excellent. Great interest attaches to the many photographic views which are reproduced of river scenery in Yugoslavia; many of these are very striking indeed and give an excellent idea not only of the hydro-electric potentialities of the country but also of its physical beauties. Much hard work and painstaking care have gone into the preparation of this volume and we offer our congratulations to the Institute of Hydraulic Engineering and to the other organisations which have been responsible for its production. The present volume is to be followed by a second volume which will elaborate the practical possibilities of utilising these resources, and finally by a third which will describe the hydro-electric installations which are already in operation.

Kempe's Engineer's Year-Book for 1957. 62nd Edition. Edited by C. E. Prockter, M.I.E.E., M.I.Mech.E., under the direction of B. W. Pendred, M.I.Mech.E., M.I.S.I. Published by Morgan Brothers (Publishers) Limited, 28 Essex Street, Strand, London, W.C.2. Two volumes. 3000 pp. Illus. Price 82s. 6d. (postage 2s. 6d.).

The work of an engineer is concerned with accurate data of all kinds and that an annual providing such data should go from strength to strength over a period of 62 years needs no other commendation of its merits except to say that it is indispensable. With Kempe's, revision is always a thorough-going process and the engineer who specialises in hydro-electric work will find proof of this in the fact that the present volume contains a reference to the new Deriaz feathering-blade Francis turbine which the English Electric Co. Ltd. are supplying to Canada for a pumped-storage scheme at Niagara. Other sections of the Year Book have also been brought up to date and, in some cases, extensively rewritten and expanded.

Proceedings of the Sixth Hydraulics Conference. Publication No. 431. Edited by Louis Landweber and Philip G. Hubbard and published by the State University of Iowa, Iowa City, Iowa, U.S.A. 1956. 276 pp. Illus.

This publication reproduces the texts of 14 papers presented to the sixth of a series of conferences arranged by the Iowa Institute of Hydraulic Research, together with short summaries of the discussions. These conferences take place at triennial intervals and each is arranged to deal with some specific subject. On the present occasion the subject chosen was the measurement of fluid flow. In his introductory remarks, Mr. Hunter Rouse, the director of the Institute, mentions that in the early days of hydraulics empiricism necessarily had to play a large part and one heritage of this has been the belief that any phenomenon of flow could be understood if only sufficient experimental data were to be accumulated; but he now considers that the time has come when the emphasis should be placed on the quality of the measurements rather than their mere quantity.

The papers form a valuable record of present-day knowledge on fluid flow and indicate on what lines further advances are being made. Space prohibits the possibility of commenting on each paper but we give the titles to indicate their scope and content:— "Experience, Theory and Experiment" (C. Truesdell—

Indiana University); "The Logic of Measurement" (Gustav Bergmann—State University of Iowa); "Indirect Methods of River Discharge Measurement" (Joseph Cragwall, Jr.—U.S. Geological Survey); "Development of the Ultrasonic Method of Discharge" (R. C. Swengel—Consultant, and W. B. Hess—Safe Harbor Water Power Corporation); "Automatic Instrumentation of the Mississippi Basin Model" (H. C. McGee—Waterways Experiment Station); "Recent Developments in Electronics Instrumentation" (P. G. Hubbard—Iowa Institute of Hydraulic Research); "Photographic Analysis of Fluid Flow" (J. H. Waddell—Fairchild Camera and Instrument Corporation); "Potential Uses of Radioisotopes in Flow Measurement" (O. M. Bizzell—Atomic Energy Commission); "Measurement of Micropressure in Liquids" (P. Eisenberg—Office of Naval Research, and J. P. Craven and J. A. Luistro—David Taylor Model Basin); "Potential-Flow Analogs and Computers" (S. C. Ling—Iowa Institute of Hydraulic Research); "Instrumentation for Studies of Low-Velocity Winds" (J. F. Ripken—St. Anthony Falls Hydraulic Laboratory); "Ultrasonic Measurement of Depth" (Laurence Batchelder—Raytheon Manufacturing Company); "Ultrasonic Instrumentation in Cavitation Research" (Murray Strasberg—David Taylor Model Basin); "Electrolytic Measurement of Low Velocities in Water" (M. C. Boyer—State University of Iowa).

Anderson Ranch Dam. U.S. Department of the Interior, Bureau of Reclamation, Denver, Colorado. 231 pp. Lithographed.

This is a further publication in the Bureau of Reclamation's "Technical Record of Design and Construction" series, and devotes the same meticulous attention to detail that has been displayed in previous publications, and which is so valuable for design study. The book is divided into four parts. The first discusses general planning and historical data, and also contains a summary of costs. Part II contains discussions of geological conditions, foundation grouting and treatment. Part III is devoted to descriptions and discussions of designs of the various structures. In this part each major structure—the dam, power plant, and spillway and outlet works—is made the subject of a separate chapter. Part IV is divided into one chapter on contract administration and one on construction operations.

The Anderson Ranch dam and power plant was described in the November 1953 issue of WATER POWER by D. L. Goodman, one of the Bureau's engineers.

Utilisation de la Statistique dans les Problèmes d'Hydraulique et d'Hydrologie. La Société Hydrotechnique de France, 199, Rue de Grenelle, Paris (VII).

This publication embodies the proceedings of a one-day conference organised last year by La Société Hydrotechnique de France to study statistical methods of resolving hydraulic and hydrological problems. During the morning session, after introductory papers by R. Gibrat (the President of the Technical Committee) and G. Darmois, papers were presented by A. Craya on the statistical interpretation of turbulence, by J. Bass on turbulence in blowers, and by J. Larrieu on the analysis of flow structures. In the afternoon, papers were presented by G. Th. Guilbaud on operational research, by G. Morlat on Halphen's laws of probability, and by G. Labaye on the determination of the economic optimum design for the spillways at Serre Ponçon.

This volume forms a supplement to the Society's publication *Mémoires & Travaux*, and, of course, is in French.

International Electrotechnical Vocabulary, 2nd edition. Group 16: Protective Relays. International Electrotechnical Commission, 1 rue de Varembré, Geneva. 6 Sw. fr.

This publication is the eighth of 22 groups which will form the second edition of this Vocabulary. It contains some 180 terms and definitions arranged under the following headings: Fundamental definitions; Terms relating to operation of relays; Main types of relays; Characteristics of operation and time; Terms relating to physical working principles; Terms relating to actuating quantity of relays; Constructional characteristics; Methods of energising relays; Fundamental characteristics of protection; Working relay elements of protection; Principles of connection of protection; Terms relating to actuating quantity of protection; Terms relating to different types of disturbances; and Types of operation of protection.

The terms and definitions are given in English and in French, and the terms only are given in Dutch, German, Italian, Polish, Spanish and Swedish. There is a separate index for each of the eight languages used.

St. Anthony Falls Multi-Purpose Test Channel. By Lorenze G. Straub and C. E. Bowers. Technical Paper No. 17, Series B. St. Anthony Falls Hydraulic Laboratory, Minneapolis, Minnesota, U.S.A.

The test channel forming the subject of this paper is 300 ft. long, 9 ft. wide and 6 ft. deep, and as originally designed in 1938 was primarily intended for flow-through tests, being provided with arrangements for precise measurements by twin volumetric basins. Even as originally conceived, however, provision had been made for the channel to be adapted to other requirements and it has subsequently been used to test spillway discharges, river bank revetments, sediment samplers, current-meter equipment, and other test purposes such as hydrofoil research. An adjustable weir gate at the discharge end of the channel permits variation of the depth of flow, and facilitates the use of the channel alternatively as a towing and wave basin.

Technologisches Wörterbuch Französisch (Technological Dictionary, French) by Kurt Stellhorn. Published by W. Girardet, Essen, 2nd Edition. 4½ in. by 6½ in., 790 pp. Price in Germany, bound in plastic boards, DM.28·80.

This German-French and French-German technological dictionary fully justifies the reputation it has gained in Germany since it first appeared in 1950. Although stress is laid on metallurgy and the machining and tooling of iron, steel and other metals, the work, with no less than 20,000 terms, has all the characteristics of a general technical dictionary; the arrangement of the words is particularly good. Technicians and translators conversant with both French and German will find this dictionary most useful.

Remote-Control Indication Equipment

A d.c. multiplexing equipment has been developed by The General Electric Co. Ltd., England, for the continuous indication, at a central control point, of the operating state of apparatus situated in remote locations. The information from up to 12 such items of equipment can be relayed to the control along only a single pair of wires, whereas, previously, one pair of service wires has been required for each unit to be monitored. This reduction in the number of service wires required can mean a considerable saving in the cost of an installation, even over relatively short distances, since cable-laying is usually expensive. Old installations can now be more extensively covered by using the existing cables to service a greater number of points.

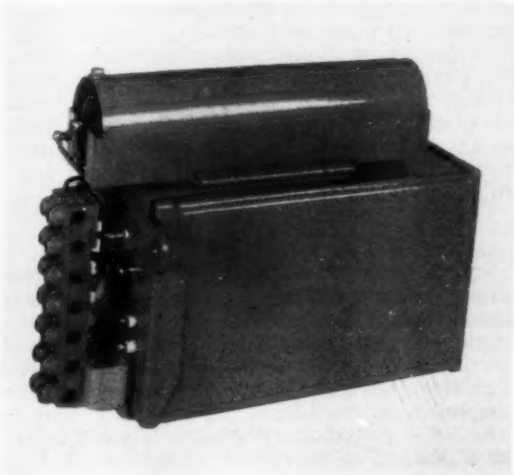

Fig. 1. Transmitter unit with battery

Initially designed for monitoring airfield control lights, the equipment can be applied to many other types of installation, such as hydro-electric schemes, where it is necessary to check quickly the operating state of equipment remote from the control point. The equipment, which uses transistors, consists of up to 12 transmitter units and a cabinet containing the corresponding receiver sub-units. Each of the transmitter units is an audio-frequency oscillator tuned to a different frequency. These units are distributed along the wires so that one is adjacent to each point to be monitored. The receiver sub-units all comprise a band-pass filter, amplifier, detector and relay. Each band-pass filter is tuned to a particular transmitter frequency. Any operation of the equipment being monitored can be arranged to switch the adjacent monitoring transmitter. At the presence of a particular oscillator tone on the wires, the relay in the corresponding receiver then operates and, by a suitable circuit, can be used to show which transmitter is working. For example, the extinguishing of an essential warning light can be signalled by the disappearance of the associated oscillator tone from the receiver.

Each transmitter unit (Fig. 1) is enclosed in a hermetically sealed can and connections are made to a terminal block. A case can be provided at the side to house a supply battery. On continuous load the battery will operate for approximately six months before replacement becomes necessary. If it is undesirable to use a battery, the transmitter will operate from a d.c. supply of 50 V. The receiver cabinet (Fig. 2) will house 12 working receiver sub-units and 12 spare sub-units or, alternatively, 24 working receiver units for operation on two pairs of wires giving a service to a maximum of 24 monitoring points. The band-pass filter and relay are in separate hermetically sealed cans.

Fig. 2. Receiver cabinet holding 12 units

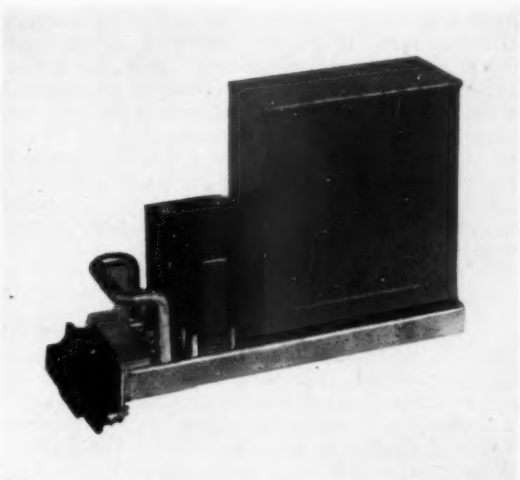

Fig. 3. Receiver sub-unit

Abstracts from the World Technical Press

Cañon del Pato Scheme, Peru

Peru's Cañon del Pato project at Huallanca on the west slope of the Andes is nearing completion. The Santa River has a fall of 1,500 ft. in 7 miles and flows down a narrow canyon; the scheme will provide the Chimbote steel mill, 54 miles away, with an initial power of 50,000 kW, to be increased ultimately to 150,000 kW. To store the 90,000 acre-ft. of water necessary to supply a 1,400 cusecs minimum flow to the powerhouse, a 177 ft. high concrete gravity dam is being built at a point where the gorge is only 100 ft. wide, and to reach the powerhouse the diverted water will travel through a 5½ mile, 18 ft. 6 in. diameter tunnel, driven through granite. The rock excavated from the tunnel amounted to 306,000 cu. yards. At the powerhouse site, four 1,430-ft. deep, 10-ft.-dia. vertical shafts were cut, three to be used for power and the fourth equipped with an elevator. The main tunnel ends in a distribution chamber set 213 ft. below the top outlet of these shafts while, at their bottom, three 7-ft. steel-lined penstocks lead into the underground powerhouse, each feeding two of the six 25,000-kW generating units operating at a head of 1,350 ft. Each generating set consists of two Pelton turbines with an alternator between. A 1,558-ft. tailrace tunnel will return the discharge to the Santa River. The project is expected to go into operation next May. Joint contractors are the Société d'Exploitations Industrielles, a French concern, and the Corporacion Peruana del Sante. (*Engineering News-Record*, Vol. 25, No. 18, November 1, 1956, pp. 51/52, 4 ff.)

Swift Dam

Work on this 510-ft. high earthfill dam, the world's highest structure of its kind, has now been started. Located on the Lewis River in south-west Washington, Swift dam, 2,100 ft. thick at the base, will be a rolled structure containing 15 million cu. yards of rock and earth. It will be 2,100 ft. long and some 55,000 cu. yards of concrete and 3,200 tons of reinforcing structural and plate steel will be incorporated in the spillway powerhouse, and intake works. The construction of the No. 1 powerhouse at the foot of the dam is scheduled for completion by mid-1958. The tail-water of this 189,000 kW plant will run 3½ miles downstream to the No. 2 powerhouse, where two generators will have 67,500 kW of capacity. (*Engineering News-Record*, November 1, 1956, p. 24, 1 f.)

Frost Hazard in Penstocks

This article, by a distinguished penstock expert, begins by laying stress on the fact that the freezing of water in penstocks is a highly improbable occurrence. However, the question arises as to what would happen if a penstock froze as completely as any domestic water-supply pipe in very cold weather. The author is of the opinion that the investigation of this problem is not entirely devoid of practical value, and proceeds from two different assumptions: solid freezing over a certain length of the penstock, and gradual freezing unaccompanied by an increase in volume, the excess water being expelled downstream. The calculation of the resulting pressures establishes that in either case it would be impossible in manufacturing practice not to exceed the limit of elasticity of the penstock walls; in other words, the possibility of avoiding permanent deformations of the penstock wall, either because of the compressibility of ice or because of a lowering of the freezing point due to compression, must be discarded. The author nevertheless advocates the use of overpressured pipes which in course of manufacture are subjected to considerable plastic deformation. Such pipes could withstand an additional deformation without risk of a burst, since the remaining possibilities of distortion in overpressured pipes before bursting are greater than those which might be caused by freezing. (G. Ferrand, *La Houille Blanche*, Vol. 11, No. 2, May-June 1956, p. 275, 7 pp.)

Brownlees Diversion Completed

After seven months of drilling and blasting in the deepest river gorge in U.S.A., Idaho Power Company have completed the 2,540-ft. long diversion tunnel which will re-route the Snake River, and pumps are now drying out the dam site for excavation to solid foundation. The rockfill Brownlee dam, scheduled for completion in mid-1958, will initially have a 360,000-kW powerhouse of four units with provision for a fifth. (*Electrical World*, November 12, 1956, p. 106, 3 ff.)

Progress at Dalles Dam

Last October, about a month ahead of schedule, the closure of the Columbia River was effected. More than 300,000 cu. yards of material was used to block the river. The top elevation of the dam, which will permit construction of the non-overflow powerhouse section reaching to the Washington shore abutment, will be 185 ft. above sea level; the earth and rockfill structure itself will be 275 ft. high, 1,000 ft. wide at the base and 2,000 ft. long at the crest. When completed, the dam will contain 3·5 million cu. yards of material. (*Engineering News-Record*, Vol. 15, No. 18, November 1, 1956, pp. 28/29, 4 ff.)

New Ideas at Table Rock

Table Rock dam, on the White River, Missouri, is to consist, when completed, of a 1,602 ft. concrete gravity section incorporating a gated spillway, the intake, short non-overflow abutment sections, and adjacent earth embankments totalling 4,821 ft. in length. The contractor is a six-firm joint venture headed by the Morrison-Knudsen and Utah Construction Companies. For the first time in the United States the concrete is being poured in 7½ ft. lifts, instead of the usual 5 ft. lifts. In conjunction with the higher lift, special box-truss hinged cantilever forms are used, which fold at mid-height, thus enabling concrete to be placed close to the form on sloping faces, and which, in addition, offer great resistance to deflection. It is claimed that the contractor's heavy investment in these novel forms is paying off in terms of a third less for handling costs. However, ultimate saving will have to depend on using the expensive forms again on subsequent jobs. To keep pace with the formwork, the

contractor is employing closed-circuit television for faster cableway control. A television screen in the travelling control tower provides the cableway operator with a close-up view of the sheaves on the hoisting machinery half a mile away. At the same time, tests are being carried out with a hydraulic concrete bucket-opening system which can be triggered at a safe distance with a hook-ended pole. Finally, to aid a conventional refrigeration system, the aggregates are pre-cooled to 30°F. by blowing cold air through the storage silos. Table Rock, for flood control and power generation, is the third major dam of a series of nine projects planned for the White River Basin (*Engineering News-Record*, September 6, 1956, p. 46, 4 pp., 5 ff.)

Grande Dixence

The two millionth cu. m. of concrete was placed at the Grande Dixence dam on October 30, 1956. Progress on other parts of this great development is as follows: Out of the 110 km. of supply tunnels included in the project, 22 km. have now been completed; the Arolla tunnel is already feeding the old Val-des-Dix reservoir, and work is proceeding on other tunnels. The supply tunnel and the pressure shaft of the underground powerhouse near Fionnay are ready for testing, and erection work in the powerhouse itself proceeds according to plan, the two first generating sets being expected to be on the line by next July. Work on the tunnel connecting Fionnay with the Nendaz underground plant is advancing satisfactorily, and the first three sets of this station are likely to begin generating by the end of 1959. (*Bulletin de l'Association Suisse des Electriciens*, Vol. 47, No. 24, November 24, 1956, pp. 113/114, 2 ff.)

Flow Studies

In this paper, the authors summarise the results they have obtained when investigating two problems which connect the mass oscillations occurring in a pressure tunnel with the waves developing in the headrace canal leading to the tunnel. The two problems are examined in separate chapters: I. Oscillations in the surge tank set up at or near the downstream end of a pressure tunnel fed by a free-flow canal; II. Oscillations in a pressure tunnel or siphon inserted between two sections of a free-flow canal. In a third chapter, the authors deal with an application of their method of calculation to a 3/100-scale model of the supply canal of the Saint-Christaud power plant. The model contains a pressure siphon inserted between an upstream canal section fed from a forebay, and a downstream section leading to the pressure tunnel and the surge tank. The theoretical and experimental graphs included in this paper show a satisfactory degree of concordance, and the authors claim that their method enables a good approximation to be arrived at. (L. Escande and J. Nougaro, *La Houille Blanche*, Vol. XI, No. 2, May-June 1956, p. 240, 100 pp., 9 ff.)

Steel Components in Hydraulic Structures

Substantial progress has been achieved in recent years in theory and practice in the use of steel components in hydraulic structures, particularly in connection with hydro-electric developments. The author of this paper first lists the ranges of application of steel in water engineering work, and emphasises the importance of model tests. The second part of the paper is devoted to steel components in hydroplants, especially gates, their frames, hoisting gears and drives. Stress is laid on the difficulties confronting the designer of submerged gates which are submitted to enormous pressures. (Professor Dr. A. Grzywienski, Vienna, *Stahlbau-Rundschau*, special issue published on the occasion of the World Power Conference, Vienna, 1956.)

Asphalt for Canal Lining

This article deals with the tests carried out by the Bureau of Reclamation with a new process designed to provide a flexible and durable wearing surface for canals and reservoirs. The official designation of the process, which is being developed in California, is "pneumatically applied emulsion mortar." The material includes sand, portland cement, emulsified asphalt and water, the best mixture arrived at by the test procedure calling for about 12% emulsified asphalt and water, 3 to 5 % portland cement, about 10% water, and the rest sand; these percentages are expressed in terms of percent of dry weight of sand. The equipment used is a modification of conventional "gunite" facilities, the mixture being sprayed through a hole by means of compressed air. The entire process has become known as "Asphalt Gunite," and the cost involved is comparable to other lining or sealing methods. (*Engineering News-Record*, September 13, 1956, p. 35, 1 f.).

Birsfelden Power Station

A detailed and abundantly illustrated description of this great base-load station is given, stress being laid on the new principles applied to the design and equipment of the plant. The first of the four 28,600 kVA generators was put on the line towards the end of 1954, and the whole station was put into commission almost exactly a year later. See also WATER POWER, February 1956, p. 45. (W. Borel, *Bulletin Oerlikon*, English Edition, No. 314, February 1956, p. 1, 24 pp., 22 ff.)

A New Silt Trap

This paper, read at a meeting of the Société Hydrotechnique de France on March 15, 1956, describes an improved type of silt trap contrived by the author with a view to ensuring the trapping of higher proportions of fine material (sand) and dealing with greater volumes of silt-laden water for a given useful capacity of the trap. Fundamentally, the apparatus consists of a chute with sidewalls inclined at at least 45° to the horizontal, and separated at its bottom throughout its whole length by a slot varying in width according to the concentration of solid materials in the discharge to be treated. The volume of discharge is regulated so as to maintain in the chute a maximum flow velocity of 0·30 m. per sec., and a system of baffles at the inlet considerably reduces turbulence. The chute is mounted on a hopper or series of hoppers (according to the length of the silt trap or the required classification of trapped material) in which water is practically still. Classification requirements may also lead to a narrowing of the chute at the top upstream and its slight widening downstream, so that the two side walls appear warped. If necessary, the hopper

or hoppers can be fitted with baffles varying in number, so as to bring the water to a standstill and to increase the resistance of the walls to water pressure. Experience has established that, owing to the low velocity of the flow, solid materials follow a downward trajectory towards the slot of the chute, below which they further sink and subsequently creep by their own gravity along the sloping walls of the hopper. The material trapped can then be removed by means of an adjustable outlet. The inner width of the hoppers may vary to a fairly wide extent without in any way affecting the working of the trap. Where required, two silt traps may be set up in a series, the finer material being trapped in the downstream apparatus. Automatic removal of the trapped material can be effected in the same manner as in other desilters. The following measurements were given by the author in the course of the discussion which followed the reading of his paper: Hoppers 1·5 to 1·8 m. deep by 0·4 m. wide; maximum width of chute at the top 0·6 to 0·7 m., with a slot 0·03 m. wide; velocity of flow in chute 0·3 m. per sec. (M. Montagné, consulting engineer, *Proceedings of Société Hydrotechnique de France*, Vol. II, 1956, p. 108, 3 pp., 3 ff., and *Houille Blanche*, Vol. 11, No. B., September 1956, p. 466.)

New French Hydro Projects

Four new EDF projects are briefly reviewed.

I.—*"Mer de Glace" Development.* The possibilities of harnessing this great glacier to energy production have been under investigation for a fairly long time, since it is estimated that the 70 sq. km. of its catchment area could yield a yearly average of 160 million of cu. m. of water. The steep slope of its main emissary, the Arveyron, is particularly favourable to the development of the head it creates. The project provides for a diversion of the glacier's waters by means of a sub-glacial intake at about 1,430 m. above sea level. A 2·2 km. long pressure tunnel would convey the water to an underground power house excavated on the left bank of the Arveyron about on a level with the village of Praz de Chamonix. Productibility of the scheme is assessed at about 115 million kWh a year, almost all summer energy. Extensive exploration borings have been carried out during last summer with regard to the layout of the intake structures, which are the main feature of the project.

II.—*Enosson.* This Franco-Swiss venture is to harness the abundant water resources of the mountain mass dominated by the Argentières Peak and Mount Dolent. For lack of a likely site in the upper valley of the Arve, which rises on the Franco-Swiss border, the large accumulation reservoir necessary (200 million cu. m.) will be sited in the Enosson "punch bowl" on Swiss soil, on the upper stretch of the Barberine. A network of supply tunnels will collect the waters of a number of Swiss and French streams, and feed the Enosson reservoir created by a 160 m. high dam with one abutment in Swiss and the other in French territory. Two power plants at Le Châtelard and La Bâtiaz, totalling 475,000 kW in capacity, will operate an aggregate head of 1,450 m. Productibility is assessed at 640 million kWh a year, almost all winter energy.

III.—*Beauvoir.* This project constitutes the final stage of the Lower Isère development downstream of the Moirans plain, and will be sited a few kilometres away from St. Marcellin, upstream of the St. Hilaire plant. The works include: a three-bay weir controlled by tainter gates 18 m. long by 13 m. high and flanked by a power house equipped with three Kaplan sets totalling 40,000 kVA; a transformer station in the vicinity of the power house; access roads and dwelling accommodation for the operating and supervision staff. Mean annual production is estimated at about 197 million kWh, and the energy generated will be fed into the St. Hilaire substation. The power house, which will operate under a head of 10·5 m., will be equipped to cope with a discharge of about 400 cu. m. per sec. The backwater in the Isère will reach as far as St. Gervais, thus creating an artificial lake 16 km. in length, but owing to the narrow bed and steep banks of the river, no more than at most 200 m. in width. The application for a construction licence in respect of this project was filed on October 29, 1956.

IV.—*Aime, Upper Isère Development.* The application filed for the construction of this plant immediately downstream of Bourg St. Maurice provides for the harnessing of the Isère waters between the maximum level of the existing balancing reservoir at Malgovert and El.650, as laid down for the point of return of the water to the river, as also the waters of the Arbonne, Ponturin and Omente streams at elevations of 810, 815 and 820 m. respectively. The gross head utilised will be 155 m. and the plant will have a maximum discharge of 50 cu. m. per sec. The works comprise: 10 km. of supply tunnels, a non-overflow surge tank opening out at the surface, a penstock laid in a trench at its upper end and in a concrete tunnel at its downstream end, and a power house equipped with two 37,000 kVA vertical sets driven by Francis turbines. Mean yearly productibility is estimated at 209 million kWh of high-quality energy, thanks to the influence of the Tignes reservoir, which, upon completion of the upstream works now in course of construction, will also collect the waters of the Upper Arc. (*La Technique Moderne, Construction*, Vol. XI, No. 12, December 1956, p. 443.)

Testing Governing Stability

This paper gives the results of the stability tests effected by the authors on one of the 40 MW Kaplan turbines of the Otttmarsheim power station on the Rhine. The main purpose of these tests was to check the laws, reduced to equations, which rule the governing stability of hydro-electric generating units. Owing to operating requirements, it was impossible to extend the tests to several units working in parallel. They were therefore restricted to the running of a single set at 15, 25 and 35 MW, this covering practically the full range of capacity of the set. Proceeding from a survey of seven governor characteristics, the authors apply harmonic analysis to the investigation of the behaviour of a generating unit by means of induced sinusoidal pulsations which give rise to oscillations in various parts of the governing system. A separate paragraph deals with the effect on stability of the lags observed. Generally speaking, the tests proved the governing equations correct, except for the servomotor which will be the special object of further tests at a later date. (Laurent & Favez, EDF Research Engineers, *Proceedings of Société Hydrotechnique de France*, Vol. II, 1956, p. 111, 18 pp., 21 ff., and *La Houille Blanche*, Vol. 11, No. B., September 1956, p. 479.)